DISTRIBUTION, ABUNDANCE, and POPULATION DYNAMICS of NORTHERN SQUAWFISH, WALLEYE, SMALLMOUTH BASS, and CHANNEL CATFISH in JOHN DAY RESEKVOIK, 1986

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CONTENTS

CONTENTS (continued)

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ABSTRACT

John Day Reservoir was sampled from 25 March to 1 September 1986 using gill nets, trap nets, boat electrofishers, hook and line, and an angler survey to collect 4,945 northern squawfish *Ptychocheilus oregonensis*, 602 walleye *Stizostedion vitreum*, 2,894 smallmouth bass *ticropterus dotomieui*, and 563 channel catfish *Ictalurus punctatus*. Distribution, abundance and population parameters of each species were examined.

Northern squawfish were distributed throughout the reservoir with densities similar in all areas except the McNary Dam boat-restricted zone where densities were 6 to 30 times those observed elsewhere. Seasonal changes in distribution were seen. Individual northern squawfish traveled widely with movements of up to 80 km observed among marked fish. Northern squawfish were the most abundant predator in John Day Reservoir. Estimated abundance of fish longer than 250 mm was 108,204 (5.6 per ha). Confidence intervals ranged from 79,102 to 143,089 and alternate estimates based on varying assumptions ranged from 98,475 to 527,851.

Northern squawfish as old as age 15 were collected. Growth rate was sex-related after age 7 and was described with von Bertalanffy equations. Annual mortality rate was estimated at 0.24 based on an average of estimates from three methods. Anglers harvested an estimated 2,121 northern squawfish but exploitation rate was 0.01 to 0.02 depending on the method of estimation. Year-class strength of northern squawfish was variable and was most highly correlated with the strength of the concurrent walleye year class, water temperature during spawning and incubation, and reservoir flow during spawning and incubation.

In April, walleye densities were greatest in McNary tailrace and declined progressively down river. After April, walleye gradually dispersed down reservoir as far as Arlington. Individual walleye traveled throughout the upper reservoir with movements up to 30 km observed. Walleye were the least abundant predator in John Day Reservoir in 1986. Estimated abundance was 14,036 fish over 250 mm in length with 95% confidence intervals of 4,520 and 36,003. Alternative estimates based on varying assumptions ranged from 11,295 to 25,768.

Walleye as old as age 12 were collected. Growth was faster in females than males and was described with von Bertalanffy equations. Annual mortality estimates ranged from 0.48 to 3.67. Anglers harvested an estimated 265 walleye from April through August. Rate of exploitation was 0.02 to 0.05. Year-class strength was variable, and the 1979 year class dominated all others.

Smallmouth bass densities were greatest in the forebay (6.0 per hectare) followed by Irrigon (2.8 per hectare), Arlington (1.1 per hectare) and McNary tailrace (0.6 per hectare). Smallmouth bass seldom moved between sampling areas. Abundance of smallmouth bass

200 mm in length and larger was estimated at 38,459 with 95% confidence intervals of 26,047 and 54,566. Alternative estimates based on varying assumptions ranged from 11,214 to 38,567.

Smallmouth bass as old as age 12 were collected. Growth was described with von Bertalanffy equations and was faster in the upper reservoir than in the lower reservoir. Annual mortality, estimated from catch curves, was 0.39 in the upper reservoir and 0.36 in the lower reservoir. Anglers harvested an estimated 7,500 smallmouth bass; two thirds in the lower reservoir. Exploitation rates estimated from harvest and population estimates were 0.94 (lower reservoir) and 0.24 (upper reservoir). Smallmouth bass year-class strength was highly variable, and trends in the lower and upper reservoir were similar except in 1985.

No differences in density of channel catfish between areas other than the BRZ could be discerned based on catch per unit effort but low catch rates resulted in low power of tests for area differences. Channel catfish density in the BRZ appeared greater than elsewhere in the reservoir. Some movements by channel catfish were noted between Irri gon and McNary tailrace areas. Channel catfish abundance in the McNary tailrace and Irrigon areas was estimated at 5,351 based on only four recaptures. Confidence intervals (95%) were 1,477 and 15,797. Anglers harvested an estimated 960 channel catfish from April through August, mostly from the John Day River.

INTRODUCTION

Construction of dams and reservoirs in the Columbia River basin has had a major negative influence on survival of juvenile anadromous salmonids migrating through the system (Raymond 1979). Estimates of mortality range between 15% and 45% (Sims and Ossiander 1981) at an individual project. A significant portion of the estimated mortality can be attributed directly to passage at the dams (Schoneman et al. 1961). A major portion of the mortality, however, has been unexplained. Predation has been proposed as a significant component of the unexplained mortality (Raymond 1979; Mullan 1980; Uremovich et al. 1980), but has not been directly quantified in any reservoir.

Because of this unexplained mortality, the Bonneville Power Administration funded this project to estimate the magnitude of juvenile salmonid losses from predation by resident fish in John Day Reservoir. The project has developed additional goals of describing the dynamics of predation and identifying potential measures for controlling predation. The project began in 1982 and has been a cooperative effort between the Oregon Department of Fish and Wildlife (ODFW) and the U.S. Fish and Wildlife Service (USFWS). ODFW has been responsible for describing abundance and population dynamics of predators, while USFWS has been responsible for information describing food habits and prey consumption rates of the predators. Detailed annual progress reports are available for both segments of the project (Gray et al. 1984; Gray and six coauthors 1985; Nigrol et al. 1985; Nigro2 et al. 1985; Nigro and six coauthors 1985; Willis et al. 1985; Gray and eleven coauthors 1986; Palmer and thirteen coauthors 1986; Poe and nine coauthors 1987).

This report is a presentation of work completed in 1986, the final year of sampling. Objectives of this work are:

1. To estimate the abundance and describe the distribution of northern squawfish *Ptychocheilus oregonensis,* walleye *Stiwstedion vitrewn,* smallmouth bass *Micropterus dolomieui* and channel catfish *Ictalurus punctatus* in John Day Reservoir.

2. To describe the growth, mortality, and relative year class strength of northern squawfish, walleye, and smallmouth bass in John Day Reservoir.

Estimates of the actual losses of juvenile salmonids to predators require the integration of information from the USFWS study and our work. A modeling approach has been adopted to organize information developed in both studies. The goal of that effort is to estimate the magnitude of predation and also to provide some insight into the dynamics of predation and the opportunities for control. Progress on objectives of estimating and modeling losses to predation are presented in a companion report jointly authored by USFWS and ODFW (Rieman et al. 1987).

METHODS AND MATERIALS

Capture and Handling

Sampling was conducted in 1986 from 25 March to 1 September (Appendix Table A-l) to mark and recapture northern squawfish, walleye, smallmouth bass, and channel catfish and to describe relative abundance. Sampling effort was partitioned equally in two-week intervals throughout the season except in the first interval which received less effort (Appendix Table A-2). Sampling after i4 August was limited to the angler survey.

Sampling stations and distribution of effort among stations were unchanged from 1984 and 1985 in John Day forebay, Arlington, Irrigon and McNary tailrace (Nigro1 et al. 1985; Nigro and six coauthors 1985: Figure 1). Additional sampling was conducted in areas between John Day forebay and Arlington (Rock Creek) and Arlington and Irrigon (Crow Butte) during sampling periods 7 and 13 (see Appendix Table A-l for dates corresponding to sampling periods) to determine whether fish moved freely among areas.

Fish were sampled using gill nets, trap nets, a boat electrofisher, and hook and line (Appendix Table A-31. Methods and gear specifications were described by Gray et al. (1984), Willis et al. (1985), NigroI et al. (1985) and Nigro and six coauthors (1985). As in previous years, USFWS provided catch, tagging, recapture and effort data.

Handling and processing of captured fish were unchanged from previous years (Nigro2 et al. 1985), except that a left pelvic fin clip and a left opercle punch were used to recognize fish marked in 1986 that had lost their tags. Channel catfish were handled and processed like other target species. Only channel catfish larger than 249 mm were marked.

Distribution and Movements

Relative abundance in areas of the reservoir was described by relative catch per unit effort (CPUE) by gears deployed in all areas (Appendix Tables A-4 to A-7). An index of relative density in each area was calculated by first standardizing CPUE of a gear in an area to a percentage of the reservoir-wide total for that gear, then averaging those percentages for each gear used. Gillnets, trap nets and electrofishers were included for northern squawfish and walleye. Comparisons were limited to electrofishers for smallmouth bass, and gillnets and trap nets for channel catfish because other gears were ineffective for those species. Each month was treated separately. Two predator size classes were also treated separately when recapture-to-at-large ratios indicated vulnerability was size related (Appendix Figures A-l to A-31.

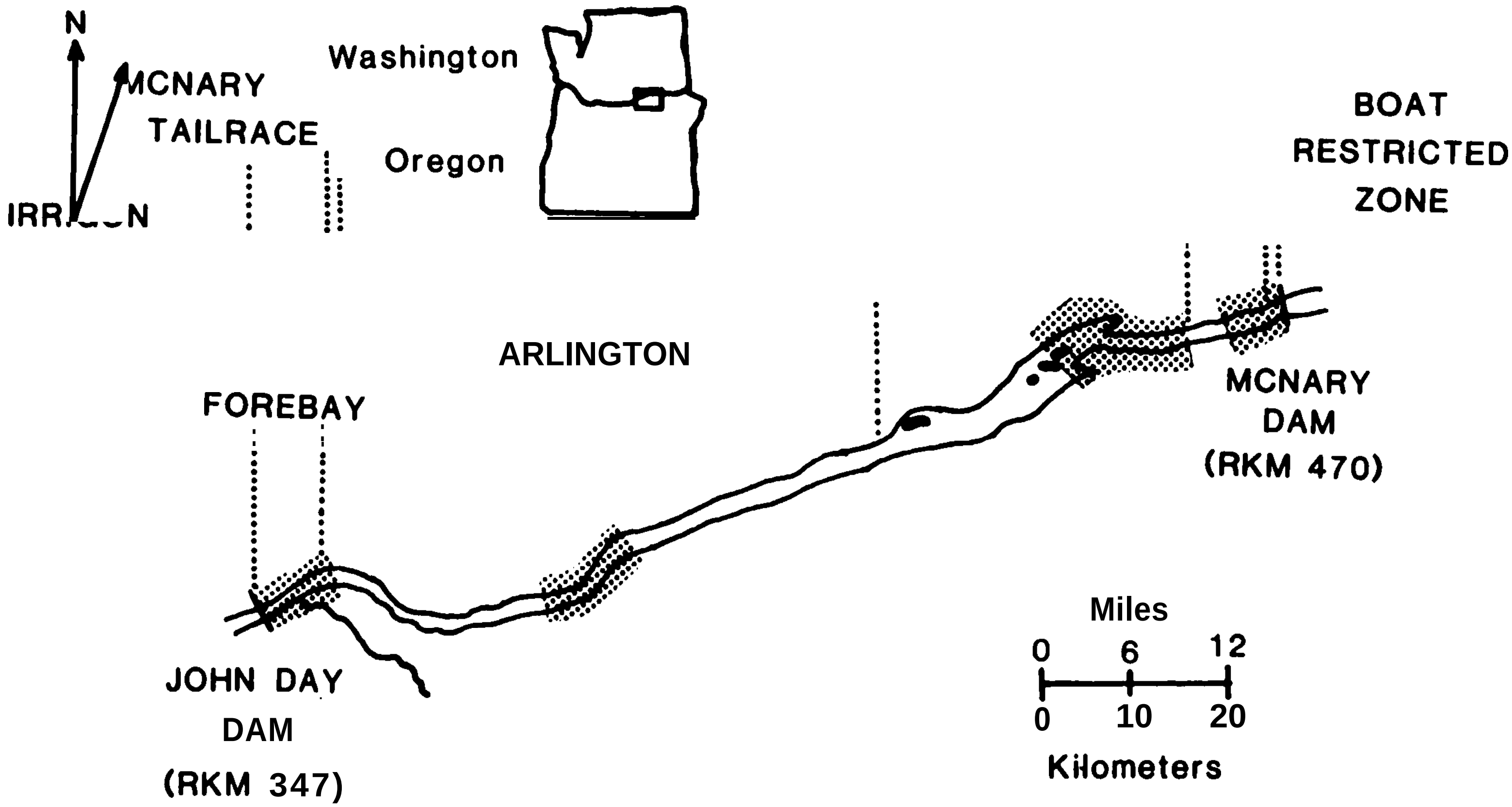

Figure 1. Sampling areas (shaded) and areas assumed to be represented by sampling in John Day Reservoir in 1984, 1985, and 1986.

Areas included for walleye, smallmouth bass, and channel catfish corresponded to our sampling areas. An additional area, the McNary tailrace boat-restricted-zone (BRZ), was also included for northern squawfish because of unusually high CPUE in that area. Relative abundance in the BRZ was described using only differences in electrofisher CPUE between the BRZ and the other four areas. Electrofishers were the only gear used inside and outside the BRZ. Electrofisher CPUE in the five areas was standardized to a percentage, as above, to estimate the proportion of the reservoir wide northern squawfish population occurring in the BRZ. The remainder of the population was distributed among the other four reservoir areas using indexes based on combined gears.

CPUE among areas was compared statistically to separate inherent differences from those related to sampling variation. A two-way analysis of variance (Neter et al. 1985) was used to identify significant differences ($P < 0.05$) in CPUE among sampling areas with gear type included as a blocking variable (Appendix Tables A-8 and A-10). A one-way analysis of variance based on electrofishing was also included to compare northern squawfish CPUE's in the BRZ with those in other areas (Appendix Table A-11). Observations included the catch in that subset of samples where gear was deployed for a standard length of time. Tukey's pairwise tests were used to identify which areas were different (Neter et al. 1985). Catch data were transformed ($\log(x + 1)$) to meet statistical assumptions (Moyle and Lound 1960; Elliott 1977).

Changes in distribution patterns among months were identified with three-way analyses of variance (Neter et al. 1985) testing gear, area, and month as main effects for each species and size class. Significant interaction effects between month and location were interpreted to mean relative distribution patterns changed with month. The BRZ was excluded from this analysis because all gears were not deployed there.

The degree of movement between sampling stations and between areas was examined by comparing locations where marked fish were released with locations where marked fish were recaptured. The timing of movements between areas was examined by comparing release dates with recapture dates.

Abundance

Abundance of northern squawfish, of walleye, of smallmouth bass, and of channel catfish in 1986 was estimated using a multiple mark and recapture method (Nigro2 et al. 1985) (Appendix B). Estimates were based on the combination of areas, sizes, and time periods that best satisfied assumptions of the estimator (Ricker 1975; Seber 1983). A series of alternative estimates were made based on various combinations of areas, sizes, and times, and estimates of removals selected to accommodate violations of assumptions. Magnitudes and confidence intervals of alternative estimates were compared with a simple estimate based on all areas, sizes, and times and no adjustments for removals by anglers.

Estimates were recalculated for 1983, 1984, and 1985 to incorporate adjustments for the assumptions and to provide estimates comparable with those made in 1986. New estimates from previous years were compared statistically with 1986 estimates using a test for differences between Schnabel estimates (Chapman and Overton 1966).

Mark and recapture assumptions which were considered included (1) closure of the population, (2) complete mixing of marked and unmarked fish, (3) equal vulnerability to capture of all fish in the population, (4) equal catchability of marked and unmarked fish, and (5) recognition of all marked fish at recapture (Ricker 1975; Seber 19831.

The assumption that populations were closed to recruitment and mortality was examined with respect to growth of fish into the tagable size range during sampling and to removals by anglers. To examine the effects of recruitment from growth on abundance estimates, minimum sizes of fish included in estimates were increased midway through the period of sampling. Increases of 25 mm in northern squawfish and 50 mm in walleye and smallmouth bass were selected corresponding to approximately half the observed annual growth increments for fish in the lower size range included in estimates. To examine effects of harvest by anglers, estimates were adjusted for period specific estimates of harvest using the method of Overton (1966).

The assumption that marked and unmarked fish mixed completely was examined with observed movements of marked fish between sampling areas. Where substantial movements among areas was observed, mixing of marked and unmarked fish in sampled and unsampled areas was assumed to be complete. No mixing was assumed where no movements between areas were observed.

Effects of varying amounts of mixing were examined, with estimates based on three degrees of movements. Estimates based on areas pooled, approximated a situation where fish mix freely into nonsampled areas. The opposite, where no movements of tagged fish out of sampled areas or untagged fish into sampled areas occurred, was approximated by expanding area-specific estimates according to relative sizes of sampled and unsampled areas. Area-specific estimates of abundance were also added without expansion for unsampled areas to approximate a situation of incomplete mixing where fish moved into areas adjacent to sampled areas but areas of mixing did not overlap.

The assumptions of closure and of mixing were also addressed by estimating abundance for a restricted period of mark and recapture sampling. Reducing the period of the experiment increases the likelihood that assumptions of closure are met (Seber 1983) and also handles the situation where seasonal changes in the degree of mixing of marked and unmarked fish occur. Seasonality of mixing was examined with radiotelemetry (NigroI et al. 1985) and movements of marked fish.

The assumption that all fish in the population were equally vulnerable to capture was examined with respect to size selectivity of our combined gear. Separate abundance estimates were made for two size classes of fish to determine the effects of sire differences in vulnerability on estimates of abundance. Small samples precluded finer stratification. Except for smallmouth bass, divisions were made where abrupt changes in vulnerability were noted (Appendix Figures A-l to A-3). Smallmouth bass were split so that sample sizes in each group were similar because no abrupt changes in vulnerability were seen.

The assumption that marked and unmarked fish were equally vulnerable to capture was examined with respect to mortality that resulted from capture and handling when marked. Short term mortality following release was investigated earlier in this study (Nigro2 et al. 19851. Delayed mortality was investigated by comparing the survival of marked fish at recapture with that of unmarked fish. The premise of this test was that marked fish would be more likely to die if marking had a long term effect on fish condition. No adjusted estimates were made to examine the effects of marked fish mortality because this mortality appeared to be low.

No adjustments for violations of the assumption that all marked fish are recognized at recapture were considered. Only trained personnel examined fish for tags and because secondary marks and tag scars were readily apparent, we felt nonrecognition was minimal.

Angler Survey and Harvest

Anglers were surveyed from 6 April through 1 September 1986 between McNary Dam and Paterson, Washington, (upper reservoir) and in John Day River and forebay (lower reservoir) (Figure 1) as in 1985 to estimate harvest and recover marked fish (Appendix Tables C-l to c-31. Methods followed those in 1985 (NigroI et al. 1985) with the following exceptions: (1) all boats were counted in the upper reservoir rather than anglers in boats, (2) all parties were interviewed regardless of whether they were angling or nonangling parties, and (3) catch of channel catfish was recorded during interviews. Boat counts were apportioned among user groups (angling or nonangling) based on proportions observed during interviews as in lower reservoir estimates.

In addition to estimating harvest based on angler effort and catch rates (Appendix Tables C-4 to C-10), harvest of unmarked fish was also estimated from voluntary returns by anglers adjusted for nonreporti ng of tags. Nonreported tags were assumed to compose 50% of the tagged fish catch by anglers (Rieman 1986). Nonreporting estimated from voluntary tag returns and the estimated harvest of tagged smallmouth bass from the angler survey in the lower pool ranged from 0.46 in 1985 to 0.48 in 1986 suggesting the assumption of 0.50 was appropriate.

Age and Growth

Scales collected from northern squawfish, walleye, and smallmouth bass from March through June in 1982 and 1986 were aged. Distances from foci to annuli and foci to margins were measured and combined with 1983 to 1985 samples to determine population age structure and growth rates. Fork length at formation of annuli (Appendix Tables D-l to D-12) was backcalculated by sex and year class. These were used to estimate mean length at various ages (Bagenal and Tesch 1978) as in 1985 (Nigrol et al. 1985). For each species and population, 10 samples per 25 mm length interval were randomly selected and independently read by two persons using standard techniques (Jearld 1983).

Backcalculated fork lengths were used to fit von Bertalanffy growth equations ($L_t = L_{oo}(1 - e^{-k(t - t_0)})$) for each species (Ricker 1975). Linear regressions of length at age (L_t) versus length at age plus one (L_{t+1}) were used to obtain initial estimates of maximum length (L_{oo}). Regressions of $\ln(L_{oo} - L_{t+1})$ versus age (t) were used to obtain the first estimates of growth coefficient (k) and t_0. Nonlinear regressions of L_t versus t using the von Bertalanffy growth equation were then applied to refine the parameter estimates and generate growth curves.

To examine the potential for bias in aging, the first ages assigned independently by two scale readers were compared with the final assigned ages for readings made in 1984 and 1986 (first and last years fish were aged). The same two readers were involved in aging all scale collections except those of walleye from 1983. Percentage of reader disagreement was calculated as the number of fish in each final assigned age group divided into the number of fish in that group whose first age was assigned differently by the two readers.

Mortal i ty

Total mortality of northern squawfish, walleye, and smallmouth bass was estimated by three methods. First, catch curves were generated from the relative age frequency in each population. The number of fish in each age group was estimated as the product of numbers in each length group (Appendix Figures E-l to E-41, corrected for vulnerability to the gear (Appendix Figures A-l to A-31, and age composition in each length group from a year-specific age-length key (Appendix Tables E-l to E-4). The relative age frequencies for the years 1983-86 (Appendix Tables E-5 to E-12) were pooled to minimize variation because of recruitment (Ricker 1975). Mortality was estimated as the slope of a line fit to a plot of the natural logarithm of age frequency against age (Ricker 1975). When the right limb of the curve was not smooth, several estimates were made by restricting the analysis to portions of the curve of similar slope. Curves were truncated with age classes that represented less than one percent of the sample.

Analysis of the relative abundance of individual year classes over several years was also used to estimate mortality. The number of each age group sampled by a single gear (gillnets for northern squawfish and walleye, electrofishers for smallmouth bass) was adjusted by effort expended with that gear (Ricker 1975). Mortality was then estimated from the abundance of each year class in successive age classes as with catch curves when three or more year classes were considered. When only two year classes were available, mortality (A) was estimated by the equation

$$A=1 - (N_2/N_1)$$

where

N_1 = Number of the year class caught in year 1, and
N_2 = Number of the year class caught in year 2.

Finally, mortality was estimated based on sequential annual mark recoveries (Ricker 1975). Because marking extended throughout a season, only recoveries in the second and subsequent years were used in the estimate. We relied primarily on our own sampling for recoveries of northern squawfish and walleye and on angler catch for recoveries for smallmouth bass. Mark recoveries included samples from all gears and angler returns. The number of recoveries from each marked group was used to estimate mortality in the same fashion as the previous year-class analysis. Mark recoveries were not corrected for sampling effort because of the variety of gear necessary to develop the sample. For that reason, estimates were restricted to data only from the period 1984-86 when sampling effort among all gears was relatively uniform. No corrections were made for tag loss not recognized by anglers.

Exploitation of northern squawfish, walleye, and smallmouth bass was approximated from tagging data and harvest-population data for 1984 through 1986. For tagging estimates we relied on tags returnedby anglers. We calculated exploitation as the ratio of tags returned to tags at large (Appendix F). Voluntary tag returns were corrected for noncompliance as in harvest estimates. Because tagging continued throughout the fishing season, exploitation was estimated for each two-week sampling period and summed to approximate exploitation for the entire season.

Exploitation was also approximated as the ratio of total harvest to abundance estimates for each species. Both approximations of exploitation were calculated reservoir-wide for northern squawfish and walleye. Exploitation for smallmouth bass was partitioned to portions of the lower reservoir (John Day River and forebay only) and upper reservoir (Paterson to McNary Dam only) because information on movement suggests discrete populations may exist.

Natural mortality was considered to be mortality from all causes other than fishing. We approximated natural mortality as the difference between total mortality and fishing mortality expressed in an instantaneous fashion and then converted it to an annual proportion (Ricker 1975). Natural mortality was also projected for each population from an empirical model that related mortality to growth coefficients and water temperature (Pauly 1980) (Appendix G).

No mortality estimates were made for channel catfish because they were not aged.

Year-Cl ass Strength

Annual variation in year-class strength of northern squawfish, walleye, and smallmouth bass was examined as in 1985 (Nigrol et al. 19851, except that data were adjusted for differences in vulnerability based on fish size. Year-class strength of channel catfish was not investigated since they were not aged. A list of environmental and biological variables possibly influencing year-class strength of each species was developed through literature search and speculation. A correlation matrix of these variables was computed to identify factors that may influence year class strength (Appendix HI.

RESULTS

Northern Squawfish

Distribution and Movements

Density of northern squawfish varied among reservoir areas. Differences in relative abundance among areas were significant in all months for northern squawfish 250 to 400 mm in length and >400 mm in length (Figure 2). Density was much greater in the BRZ than elaewhere in the reservoir for both size classes. No difference in relative abundance was observed between Arlington, irrigon, and McNary tailrace areas. Density in the forebay was similar tc areas away from the dam.

Among 250 to 400 mm fish, differences in patterns of relative abundance among months were not significant ($F = 1.1$; $df = 12,1928$; $P = 0.33$). Among fish greater than 400 mm in length, differences in patterns of relative abundance among months were significant ($F = 1.8$; $df = 12,1928$; $P = 0.04$), but no pattern in monthly change could be discerned.

Marked northern squawfish released in any area were often caught in other sites within the area and in other sampling areas (Table 1). Movement between areas often occurred within relatively short periods of time (Figure 3).

Table 1. Number of marked northern squawfish released and recaptured by area, John Day Reservoir, 25 March to 1 September 1986. Numbers in parentheses are the subset of fish recaptured in the same station where released.

Area released	Number released	Area recaptured						
		F	R	A	C	I	M	B
Forebay (F)	435	8(2)	--	1	--	--	--	--
Rock Creek (R)	43	1	0	1	--	--	--	--
Arlington (A)	334	--	--	7(1)	--	1	--	3
Crow Butte (C)	54	--	--	--	1	--	--	--
Irrigon (I)	367	--	--	--	--	5(4)	4	2
McNary tailrace (M)	380	--	--	--	--	3	11(6)	6
Boat restricted zone (B)	269	--	--	--	1	--	--	2(2)

Abundance

Abundance of northern squawfish in 1986 was estimated at 108,204 fish greater than 250 mm in length (5.6 fish per hectare). Confidence intervals (95%) ranged from -27% to +32% (Table 2).

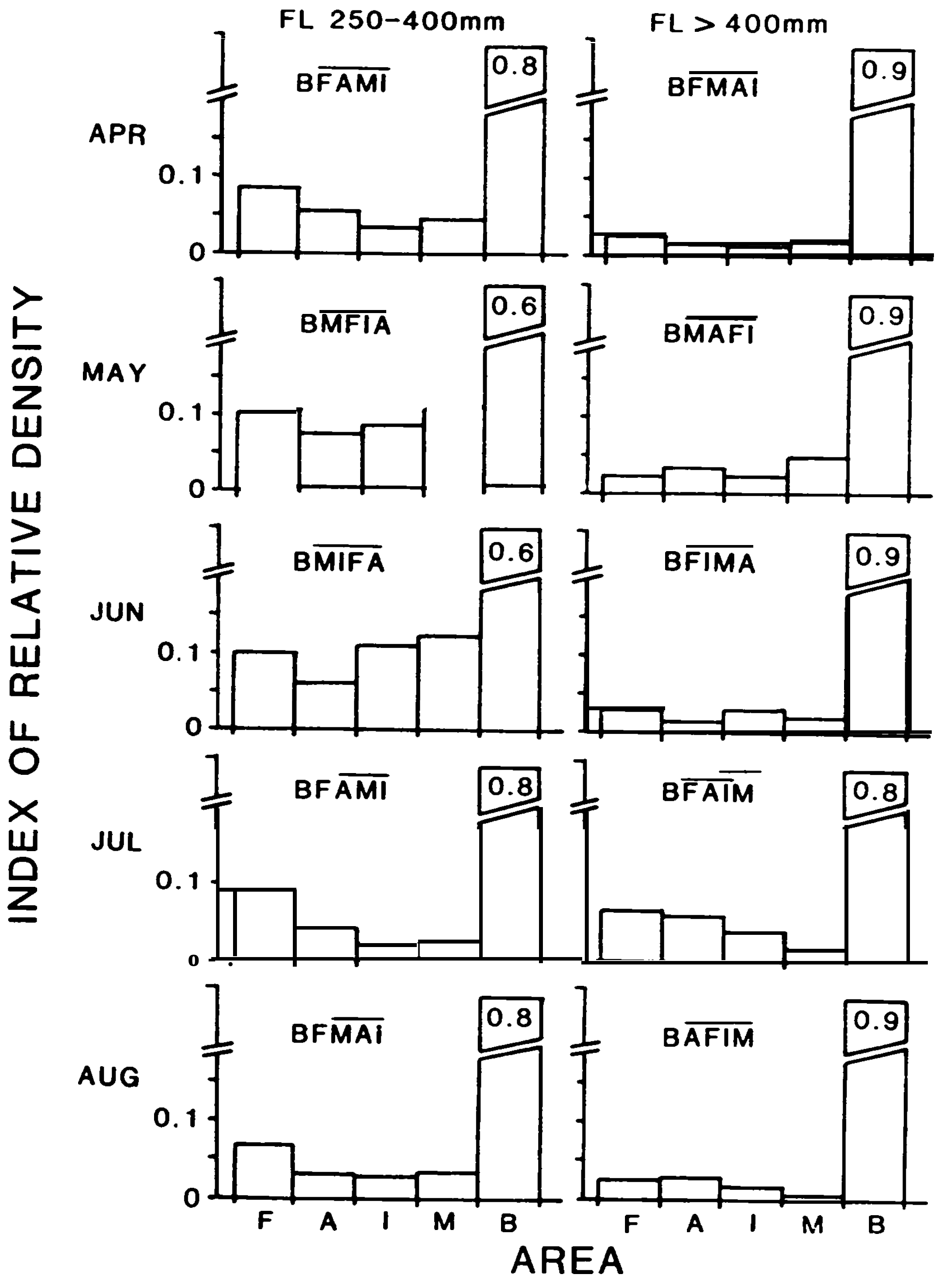

Figure 2. Indexes of northern squawfish density in John Day Reservoir based on catch per unit effort. Areas include forebay (F), Arlington (A), Irrigon (I), McNary tailrace (M) and McNary boat-restricted zone (B). Results of tests for pairwise differences are included for each month and size class.

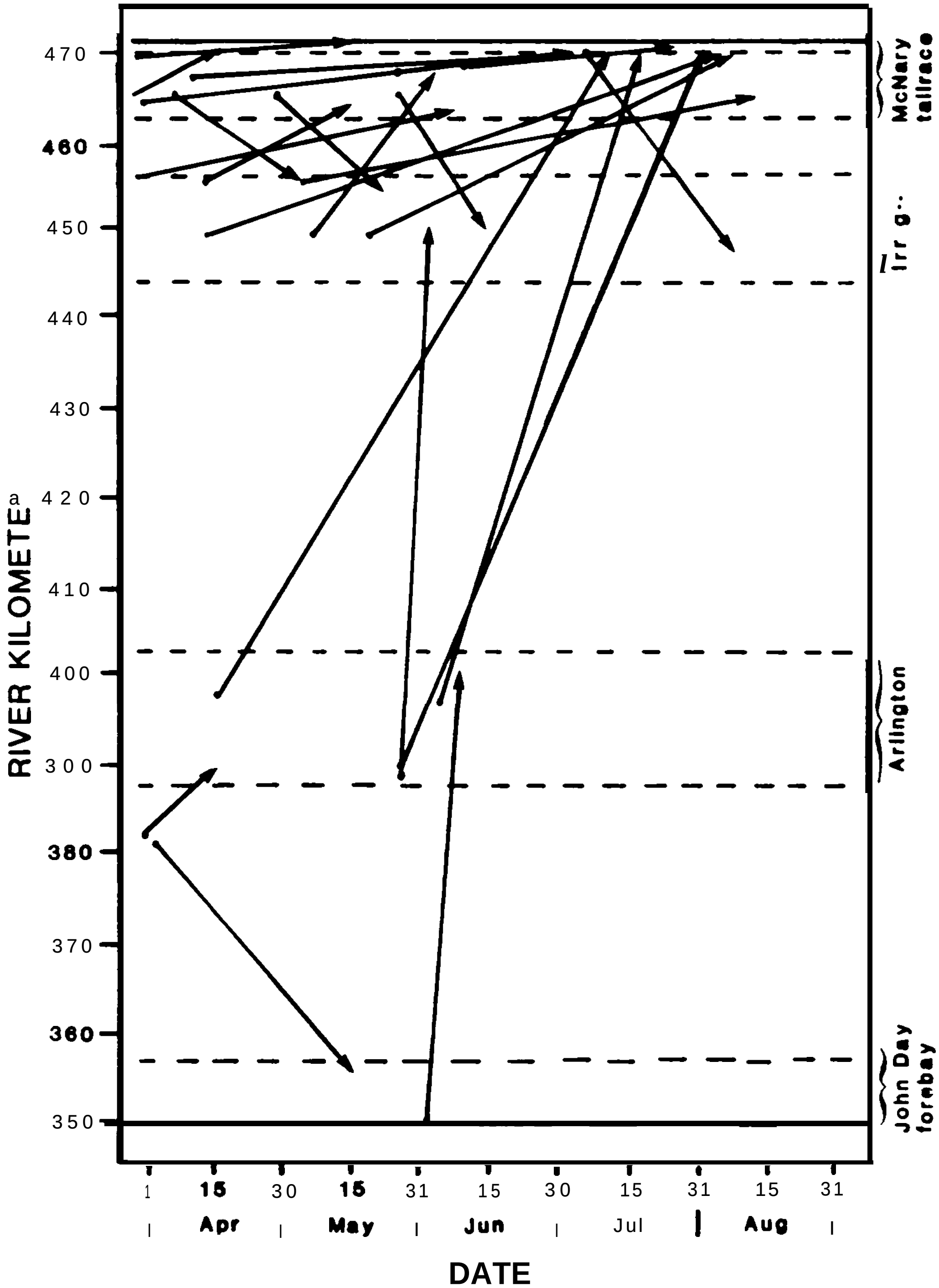

Figure 3. Movement of marked northern squawfish recaptured in areas other than where marked, John Day Reservoir, 1986. Areas sampled are indicated by brackets. Dot indicates date and location of tagging. Tip of arrow indicates date and location of recovery.

Estimates from 1984 through 1986 have increased approximately 15-20% each year (Table 2).

Table 2. Number of northern squawfish in John Day Reservoir, 1983-86, and statistical tests for differences from the 1986 estimate. Estimates are based on all areas, size classes and periods pooled with no adjustments for angler harvest.

Year	Estimated abundance	95% Confidence limits		Test (vs 1986)	
		Lower	Upper	t	P [b]
1983a	44,624	35,204	56,566	4.97	a.01
1984	77,183	61,295	97,189	1.91	0.06
1985	88,619	70,264	111,768	1.17	0.24
1986	108,204	79,102	143,089	--	--

a Sampling in 1983 covered a s a er portion of the reservoir than in subsequent years.
b Probabilities < 0.05 indicate significant differences from the 1986 estimate.-

Summing separate estimates by sampling area, with and without expansions, greatly increased the estimate of abundance (Table 3). Estimating abundance separately by size classes had some affect on the magnitude of the estimate but sacrificed precision. Restricting the duration of marking and recapture had little effect other than a reduction in precision. Adjustments for harvest and recruitment because of growth also had little effect.

No long-term effects of marking on fish condition could be discerned from comparisons of survival of marked and unmarked fish at capture. Eight percent of marked northern squawfish and 5% of unmarked fish died at capture, but the difference was not significant ($X2 = 1.3$; $df = 1$; $P = 0.26$).

Harvest

Anglers harvested an estimated 2,107 unmarked northern squawfish from April through August in the portion of the reservoir surveyed. Angler harvest of marked fish was estimated at 12 based on the angler survey and estimated at 14 based on voluntary tag returns. Eighty percent of these fish were taken in the lower reservoir and most were harvested in June and July. Anglers kept fish ranging from 150 to 475 mm in length (average = 314 mm) (Appendix Table C-11). Estimated harvest in the upper and in the lower reservoir was similar in all years in which a comparable area was surveyed (Table 4).

Table 3. Alternative estimates of northern squawfish abundance in 1986, based on various adjustments to accommodate assumptions. Effects of changing assumptions on magnitude and precision of abundance estimate of northern squawfish were calculated relative to an estimate made using all areas, times, and sizes of northern squawfish pooled.

Adjustment	Related assumptions	Abundance Estimate	Abundance change	Confidence Limits Estimate	Confidence Limits change[a]
None	Mixing, equal vulnerability closure	108,204	--	-27%, +32%	- -
Expand subarea estimates	No mixing of marks	527,851	+388%	-77%, +326%	-522%
Separate estimates by subarea	Limited mixing of marks	235,202	+117%	-77%, +482%	-796%
Separate estimates by size class	Size-related vulner-ability	131,817	+22%	-401, +55%	-60%
Account for harvest	Removals significant	109,082	+1%	-27%, +55%	0%
Increase size limits with time	Recruitment because of growth	102,533	-5%	-27%, +32%	0%
Restrict duration of marking and recapture	Immigration, emigration, recruitment, mortality	98,475	-9%	-39%, +53%	-55%

[a] *Average of upper andlower limit percentage changes, minus sign indicates widening of confidence interval.*

Table 4. Estimated harvest of northern squawfish by anglers from portions of John Day Reservoir, 1983-86. Estimates include the period June through August in 1983 and April through August in 1984 through 1986.

Year, fishing area, method of estimation	Marked	Unmarked
1983		
Lower area:		
Voluntary returns[a]	4	0
Upper area:		
Effort x CPUE[b,c]	1	88
Voluntary returns	13	0
1984		
Lower area:		
Voluntary returns[a]	6	0
Upper area:		
Effort x CPUE[b,d]	30	239
Voluntary returns[a]	22	0
1985		
Lower area:		
Effort x CPUE[b,e]	7	1,635
Voluntary returns[a]	9	0
Upper area:		
Effort x CPUE[b]	0	362
Voluntary returns[a]	10	0
1986		
Lower area:		
Effort x CPUE[b]	6	1,658
Voluntary returns[a]	5	0
Upper area:		
Effort x CPUE[b]	6	437
Voluntary returns"	9	0

a Expanded from observed for 50% nonreporting mte, includes areas beyond where anglers surveyed.
b Catch per unit effort estimated from angler survey.
c 1983 angler survey was limited to McNary Tailrace.
d Upper reservoir was expanded to area above Paterson in 1984.
e Lower reservoir including John DAy River and forebay was added to angler survey in 1985.

Age and Growth

Ages of northern squawfish in our 1986 samples ranged from 1 to 15 years (Appendix Table E-l). Estimated growth of female and male northern squawfish was similar until age 6 when male growth slowed (Figure 4).

Reader agreement of first age determinations of northern squawfish was variable but declined as age and fork length increased. Agreement between readers on first aging increased between 1984 and 1986. In 1984 at least one reader initially assigned an age different from the final age on over 50% of age 3 and older northern squawfish (Figure 5). In 1986 this occured on fish age 9 and 01 der.

Mortality

The adjusted age composition for northern squawfish from 1983-86 (Appendix Table E-6) pooled to generate a catch curve did not provide a consistent estimate of mortality over all ages. The right limb of the curve (Figure 6) was not smooth. Annual mortality estimated assuming complete recruitment and stable annual mortality after age 4 was 0.23. The shape of the curve suggests mortality could change with age. An estimate for the age 4 to age 7 portion was 0.18. Mortality estimated from age 10 at an obvious break in the slope of the curve was 0.50.

Mortality of northern squawfish estimated by cohort analysis over two age classes ranged from 0.07 to 0.57 (Table 5).

Table 5. Mortality estimated from cohort analysis of effort-adjusted age frequencies for northern squawfish sampled with gillnets in John Day Reservoir 1984-86.

Year Class	Age classes included in estimates	Mortality
1981	4-5	0.15
1980	5-6	0.10
1979	6-7	0.07
1978	7-8	0.35
1977	8-9	0.20
1976	9-10	0.18
1975	10-11	0.57
1974	11-12	0.21
1973	12-13	U.31

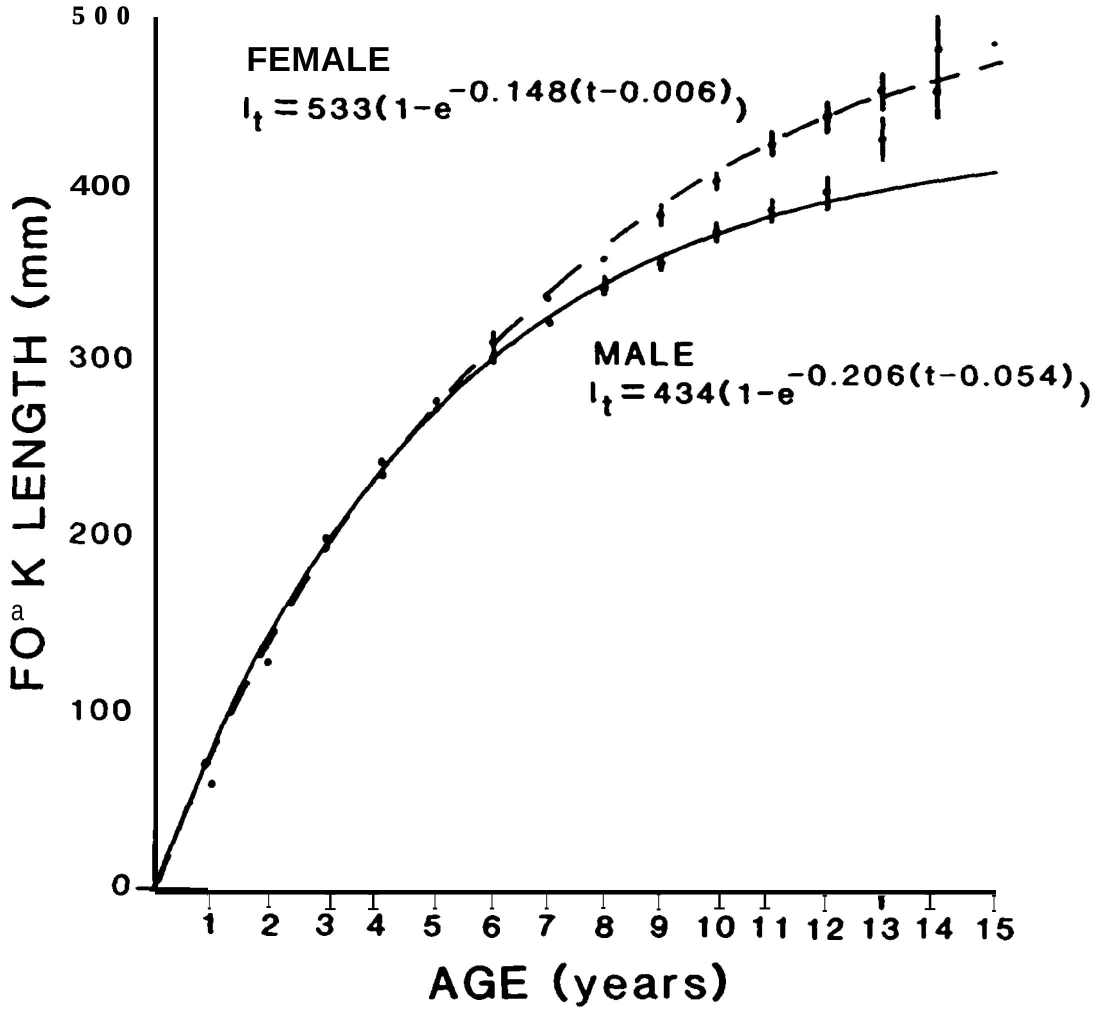

Figure 4. Mean backcalculated fork lengths with $\pm$95% confidence intervals and with growth curve predicted by Von Bertalanffy equation for male and female northern squawfish, John Day Reservoir, 1982-1986.

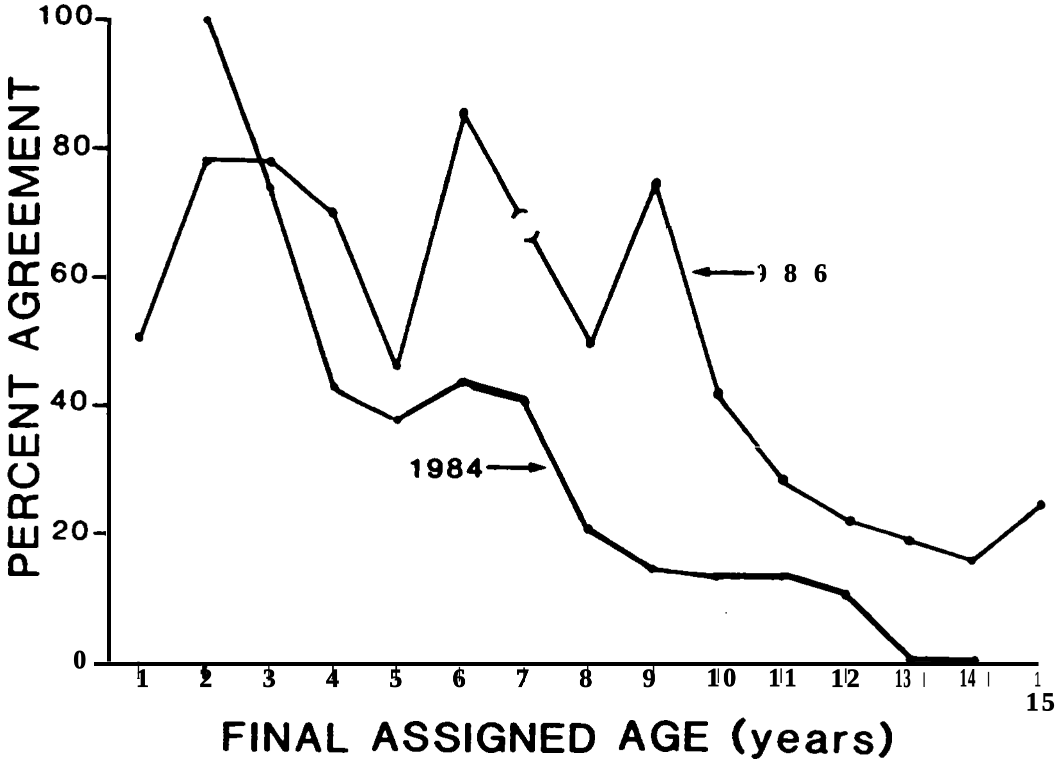

Figure 5. Agreement between first age and final assigned age of northern squawfish from scale readings made in 1984 and 1986, John Day Reservoir. No samples from age 7 fish were collected in 1986.

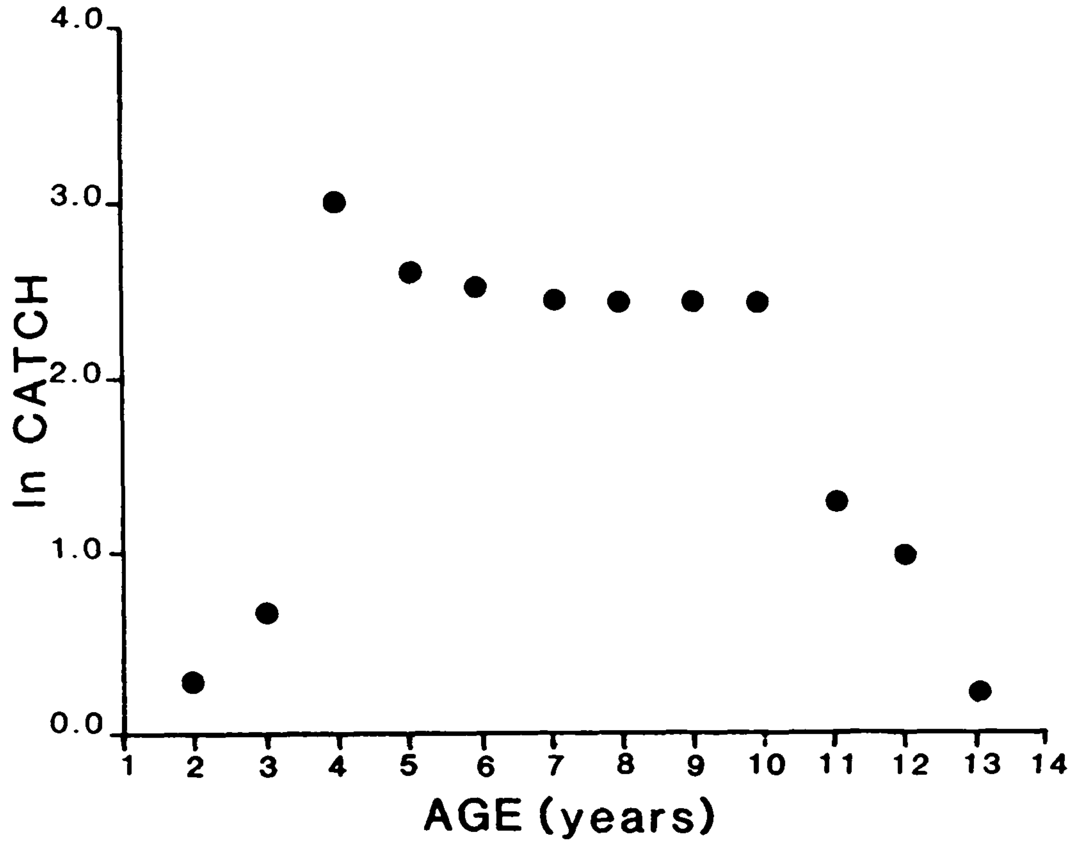

Figure 6. Catch curve of northern squawfish in John Day Reservoir 1983-86.

Mortality of northern squawfish estimated from annual mark recoveries averaged 0.60 (Table 6). Most (73%) of the marks recovered were from fish in excess of 400 mm suggesting that the estimate was representative only of older fish.

Table 6. Mortality estimated from recoveries of marked northern squawfish in years following marking in John Day Reservoir 1984-86.

Year Marked	Number Marked	Year Recovered 1984	1985	1986	Mortality
1982	1331	57	43	18	0.57
1983	2461	97	46	9	0.70
1984	2573	--	105	48	0.54

Estimates of exploitation of northern squawfish for 1986 and preceding years were low (Table 7). Estimates were 0.02 for the tagging data and 0.01 for harvest-population data.

Table 7. Exploitation of northern squawfish in John Day Reservoir 1984-86.

Year	Tag return data	Harvest population data
1984	0.03	0.003
1985	0.01	0.02
1986	0.02	0.02

Because exploitation was low, total mortality presented earlier may also be considered an estimate of natural mortality. Annual natural mortality predicted by the method of Pauly (1980) was lower than most of our estimates of total mortality at 0.24 (Appendix G).

Year-class Strength

Year-class strength of northern squawfish has varied and may be cyclic (Figure 7). Northern squawfish year class strength was most highly correlated (r = -0.87) with concurrent walleye year-class strength (Appendix Table H-l). Mean daily water temperature (r = -0.63) and reservoir flow during spawning and incubation (r = 0.63) were correlated with northern squawfish year-class strength, but they were also highly correlated with each other (r = 0.95).

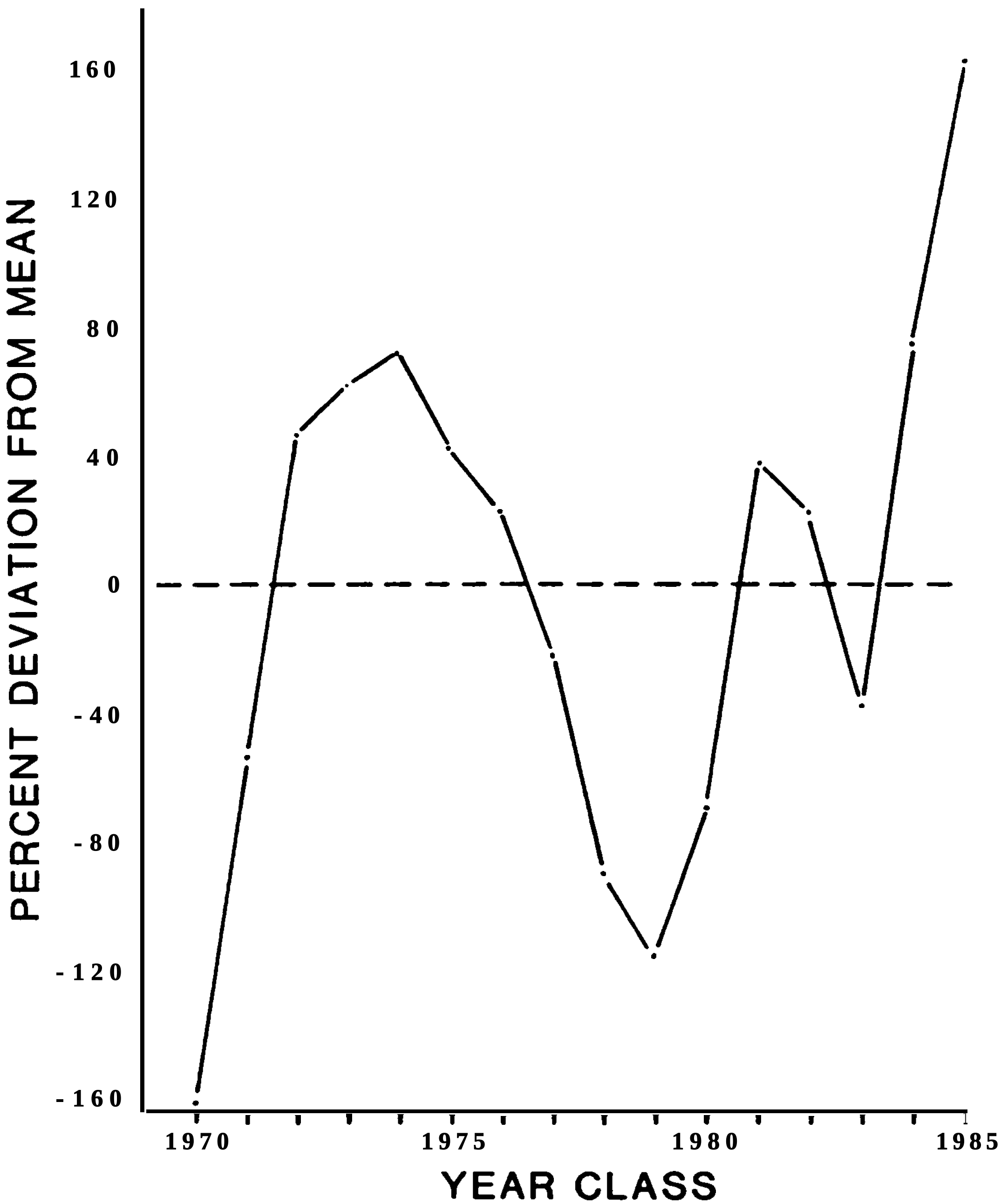

Figure 7. Relative year class strength of northern squawfish in John Day Reservoir, 1970-85.

Walleye

Distribution and Movements

Walleye density varied among reservoir areas. Differences in relative abundance between areas were significant in at least one pair of areas in four of five months for walleye 250 to 500 mm in length and in 3 of 5 months for walleye larger than 500 mm (Figure 8). Walleye density was generally highest in McNary tailrace. Few walleye were captured in forebay or Arlington areas.

Seasonal change in distribution was apparent. Among small (250-500 mm) walleye, density was relatively high in McNary tailrace from April through July, then declined to levels comparable to Irrigon in August. A decline in relative abundance in McNary tailrace and an increase in Irrigon and in Arlington were noted among large walleye (>500 mm) from April through July (Figure 81. Monthly differences in patterns of relative abundance were significant in both small ($F = 2.0$; df = 12,1928, $P = 0.02$) and large ($F = 7.3$; df = 12,1928; $P < 0.01$) size groups of walleye.

Marked walleye released in McNary tailrace were often captured at sites and areas other than where released (Table 8). All recaptures in other areas were down river from the original tagging location (Figure 9).

Table 8. Number of marked walleye released and recaptured by area, John Day Reservoir, 25 March to 1 September 1986. Numbers in parentheses are the subset of fish recaptured in the same station where released.

Area released	Number released	Area recaptured						
		F	R	A	C	I	M	B
Forebay (F)	0	0	--	--	--	--	--	--
Rock Creek (R)	0	--	0	--	--	--	--	--
Arlington (A)	18	--	--	0	--	--	--	--
Crow Butte (c)	8	--	--	--	0	--	--	--
Irrigon (I)	89	--	--	--	--	0		--
McNary tailrace (M)	247	--	--	--	1	1	7(4)	--
Boat restricted zone (B)	2	--	--	--	--	--	1	0

Abundance

Walleye abundance in 1986 was estimated at 14,036 fish over 250 mm in length (0.7 fish per hectare) with 95% confidence intervals of -68% and +156%. Estimates were similar in all years (1984-86) when sampling effort was distributed similarly (Table 9).

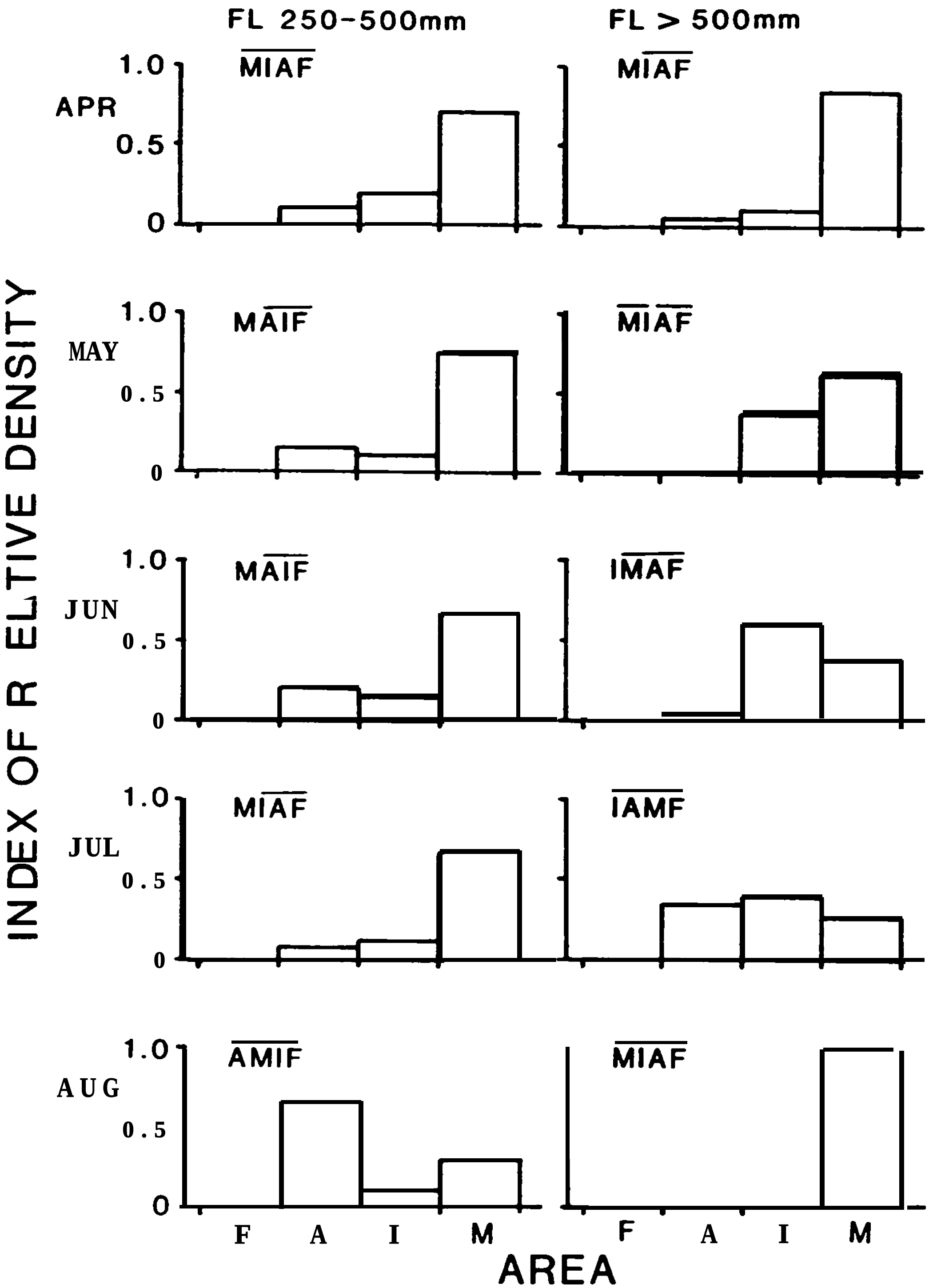

Figure 8. Indexes of walleye density in John Day Reservoir based on catch per unit effort. Areas include forebay (F), Arlington (A), Irrigon (I), McNary tailrace (M) and McNary boat-restricted zone (B). Results of tests for pairwise differences are included for each month and size class.

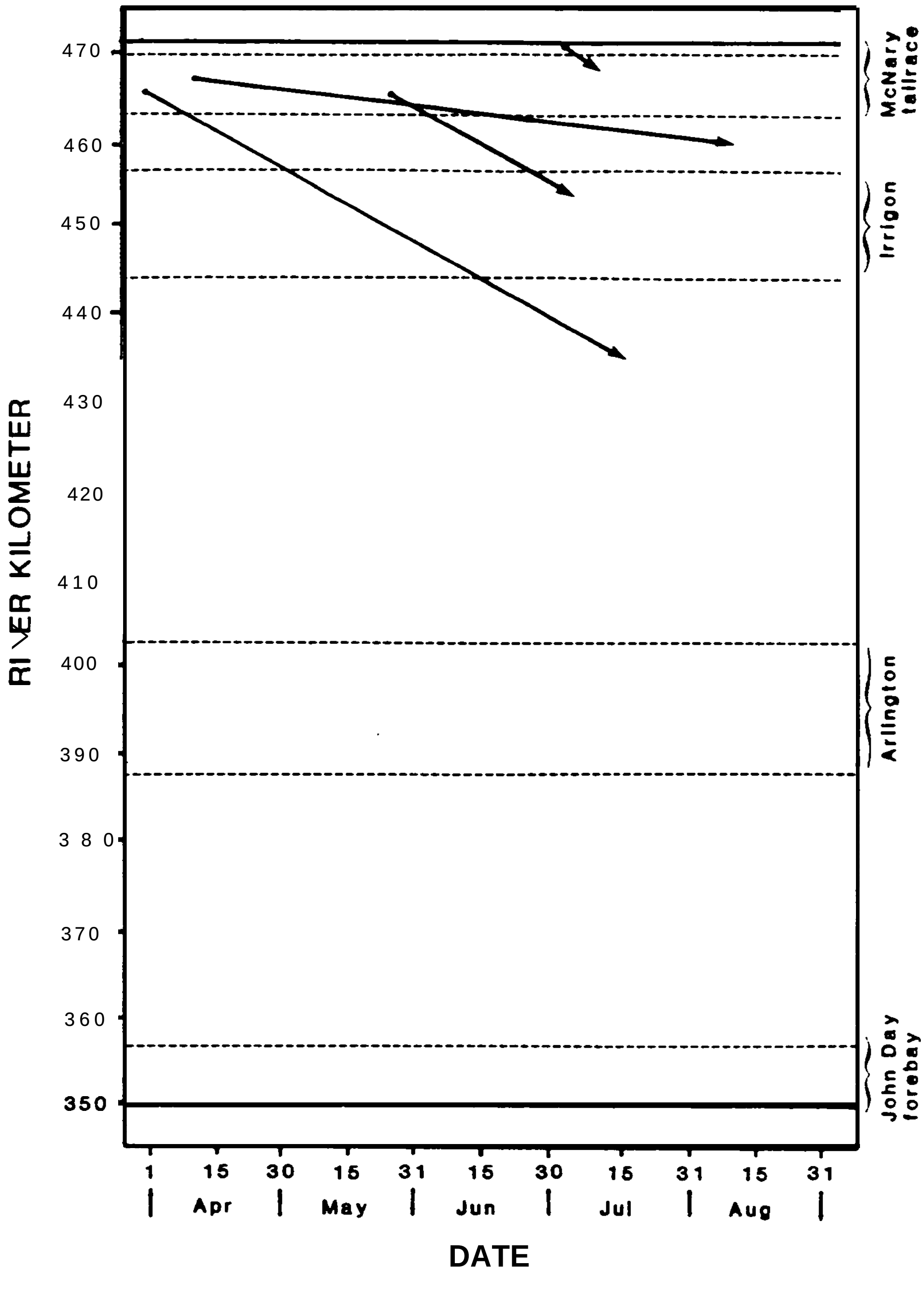

Figure 9. Movement of marked walleye recaptured in areas other than where marked, John Day Reservoir, 1986. Areas sampled are indicated by brackets. Dot indicates date and location of tagging. Tip of arrow indicates date and location of recovery.

Table 9. Number of walleye in John Day Reservoir, 1983-86, and statistical tests for differences from the 1986 estimate. Estimates incorporate April-June samples, all areas and sizes were pooled, and no adjustments were made for estimated angler harvest.

Year	Estimated abundance	95% Confidence Limits		Test (vs 1986)	
		Lower	Upper	t	P[b]
1983[a]	4,896	3,262	6,977	2.49	0.01
1984	13,042	6,573	23,006	0.40	0.69
1985	18,426	7,236	39,855	0.16	0.87
1986	14,036	4,520	36,003	--	--

[a] *Sampling in 1983 covered a smaller portion of the reservoir than in subsequent years.*

[b] *Probabilities* < 0.05 *indicate significant differences from the 1986 estimate.*

Restricting the duration of mark and recapture sampling and increasing size limits over the period of sampling had a large effect on estimates of walleye abundance (Table 10). Summing separate estimates for each area, with and without some expansion, also had an effect because no walleye marked in Irrigon were recaptured so that abundance in that area could not be estimated. Estimating abundance separately for size classes of unequal vulnerability had little affect on the magnitude of estimates but greatly reduced precision. Adjustments for removals by anglers caused little change in estimates.

No long-term effects of marking on fish condition could be discerned from comparisons of survival of marked and unmarked fish. No marked walleye and 10% of unmarked walleye died in handling.

Harvest

Anglers harvested an estimated 258 unmarked walleye from April through August in the portion of the reservoir surveyed. Angler harvest of marked fish was estimated at 6 based on the angler survey and 7 based on voluntary tag returns. All of the observed harvest occurred in the upper reservoir. Harvest varied seasonally with most fish taken after July. The majority of walleye harvested were at least 500 mm in length and the average length was 637 mm (Appendix Table C-11).

Estimated harvest was similar to that in 1984 and 1985 but was less than in 1983 (Table 11). Estimates of marked fish harvest based on the angler survey and voluntary returns were similar.

Table 10. Alternative estimates of walleye abundance in 1986, based on various adjustments to accommodate assumptions. Effects of changing assumptions on magnitude and precision of abundance estimate of walleye were calculated relative to an estimate made using all areas, times, and sizes of walleye pooled.

Adjustment	Related Assumptions	Abundance Estimate	Abundance change	Confidence Limits Estimate		Confidence Limits change[a]
None	Mixing, equal vulnerability, closure	25,768	--	-68%	+156%	- -
Expand subarea estimates	No mixing of of marks	11,295[b]	-56%	-68%,	+156%	0%
Separate estimates by subarea[a]	Limited mixing of marks	11,295[b]	-56%	-68%,	+156%	0 %
Separate estimates by size class	Size-related vulner-ability	23,445	-9%	-81%	+356%	86%
Account for harvest	Removals significant	25,749	0%	-68%,	+156%	0 %
Increase size limits with time	Recruitment due to growth	19,576	-24%	-68%	+157%	0 %
Restrict duration of marking and recapture	Immigration, emigration, recruitment, mortality	14,036	-46%	-68%,	+157%	0 %

a Average of upper and lower limit percentage changes, minus sign indicates widening of confidence intervat.

b No marked fish were recaptured in Irrigon hence this estimate includes McNary Tailrace only.

Table [illegible]. Estimated harvest of walleye by anglers from portions of John Day Reservoir, 1983-86. Estimates include the period June through August in 1983 and April through August in 1984 through 1986.

Year, fishing area, method of estimation	Marked	Unmarked
1983		
Lower area:		
Voluntary returns[a]	0	0
Upper area:		
Effort x CPUE[b,c]	8	457
Voluntary returns[a]	43	0
1984		
Lower area:		
Voluntary returns[a]	0	0
Upper area:		
Effort x CPUE[b,d]	25	284
Voluntary returns[a]	32	0
1985		
Lower area:		
Effort x CPUE[b,e]	0	0
Voluntary returns[a]	0	0
Upper area:		
Effort x CPUE[b]	8	227
Voluntary returns[a]	24	0
1986		
Lower area:		
Effort x CPUE[b]	0	18
Voluntary returns[a]	0	0
Upper area:		
Effort x CPUE[b]	6	258
Voluntary returns[a]	7	0

a *Expanded from observed for 50% nonreporting rate, include areas beyond where anglers surveyed.*
b *Catch per unit effort estimated from angler survey.*
c *1983 angler survey was limited to McNary Tailrace.*
d *Upper reservoir was expanded to area above Peterson in 1984.*
e *Lower reservoir including John Day River and forebay was added to angler survey in 1985.*

Age and Growth

Walleye aged in our samples ranged from 1 to 12 years (Appendix Table E-21. Growth of walleye described from backcalculated length-at-age was faster among females than males (Figure 10). The von Bertalanffy model of growth fit data for both sexes well with the exception of age 1 females. Percent reader agreement of first age determination of walleye decreased as final assigned age and fork length increased (Figure 11). Percent agreement between readers on first aging increased between 1984 and 1986. In 1984 at least one reader initially assigned an age different from the final age on over 50% of age 7 and older walleye. In 1986 this occurred on fish age 10 and older.

Mortality

The catch curve for walleye generated by pooling adjusted age frequencies for 1983-86 (Appendix Table E-8) was broadly domed (Figure 12) and different mortality was estimated for different age groups. Mortality for ages 6 to 9 was 0.56 and for ages 7 to 9 was 0.67. Removal of the strong 1979 year class from the analysis resulted in a mortality estimate of 0.52. Mortality estimated by cohort analysis ranged from 0.15 for fish of ages 2-3 to 0.48 for fish of ages 7-9 (Table 121. Mortality estimated from annual walleye mark recaptures ranged from 0.34 to 0.81 with a mean of 0.53 (Table 13).

Exploitation of walleye estimated by tag returns ranged from 0.02 to 0.07 and was higher than that estimated from harvest-population data (Table 14). Mean exploitation from tag returns was 0.05 compared with 0.02 from the latter method.

Natural mortality predicted for walleye based on growth coefficients and mean reservoir temperature was 0.37 for females and 0.33 for males (Appendix G). Natural mortality estimated using a total annual mortality ranging from 0.50 to 0.60 and exploitation of 0.05 ranged from 0.45 to 0.54.

Year-class Strength

The 1979 year class was dominant through all years of available data (Figure 13). Variables best correlated with walleye year-class strength were flow during spawning and incubation (r = -0.491, length obtained by age 1 (r = 0.441, and strength of the preceding year class (r = 0.40) (Appendix Table H-2).

Smallmouth Bass

Distribution and Movements

Densities of smallmouth bass varied among reservoir areas. Differences in relative abundance among areas were significant in al 1 months and size groups except for small fish in July and large

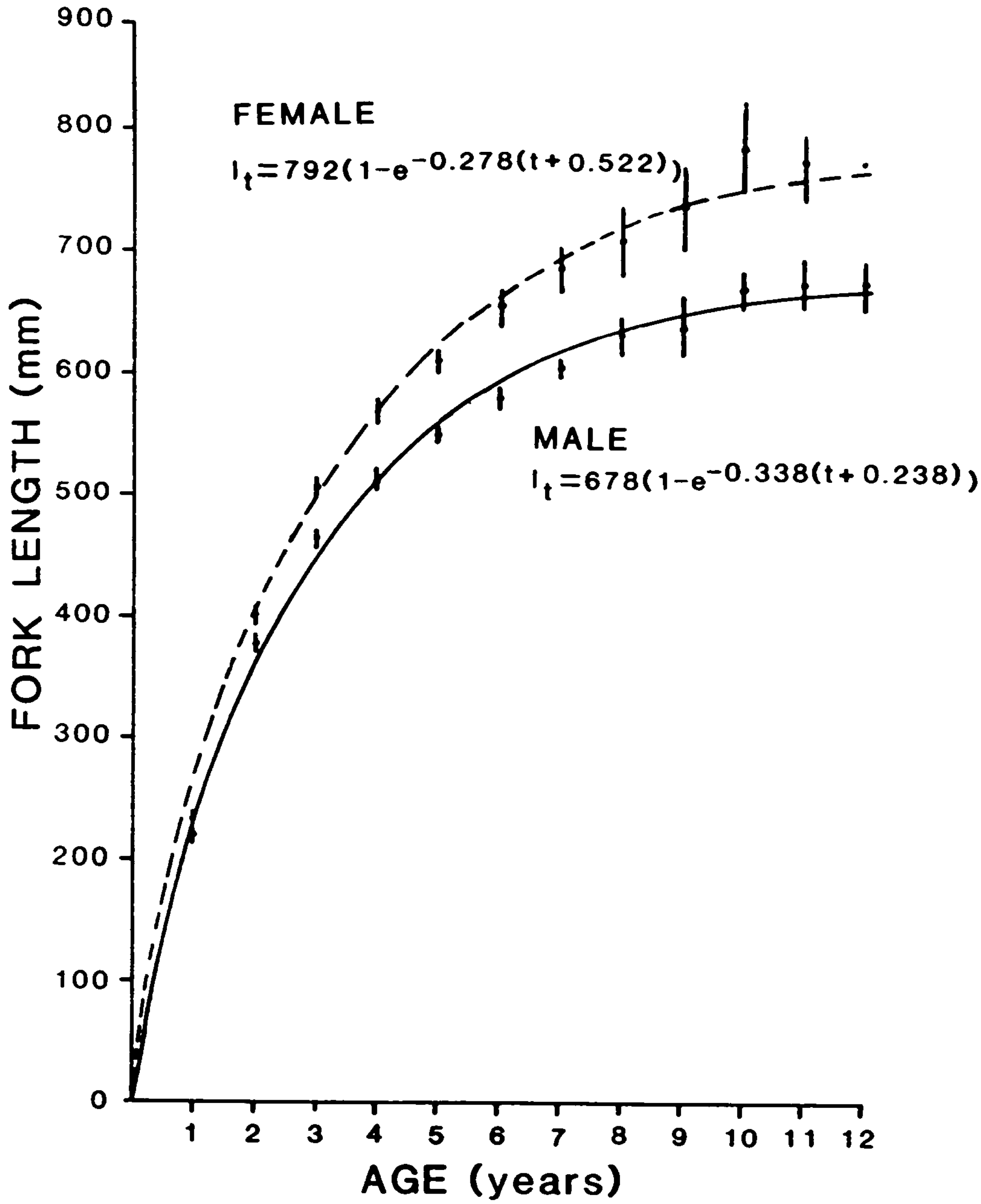

Figure 10. Mean backcalculated fork lengths with ±95% confidence intervals and with growth curve predicted by Von Bertalanffy equation for male and female walleye, John Day Reservoir, 1982-1986.

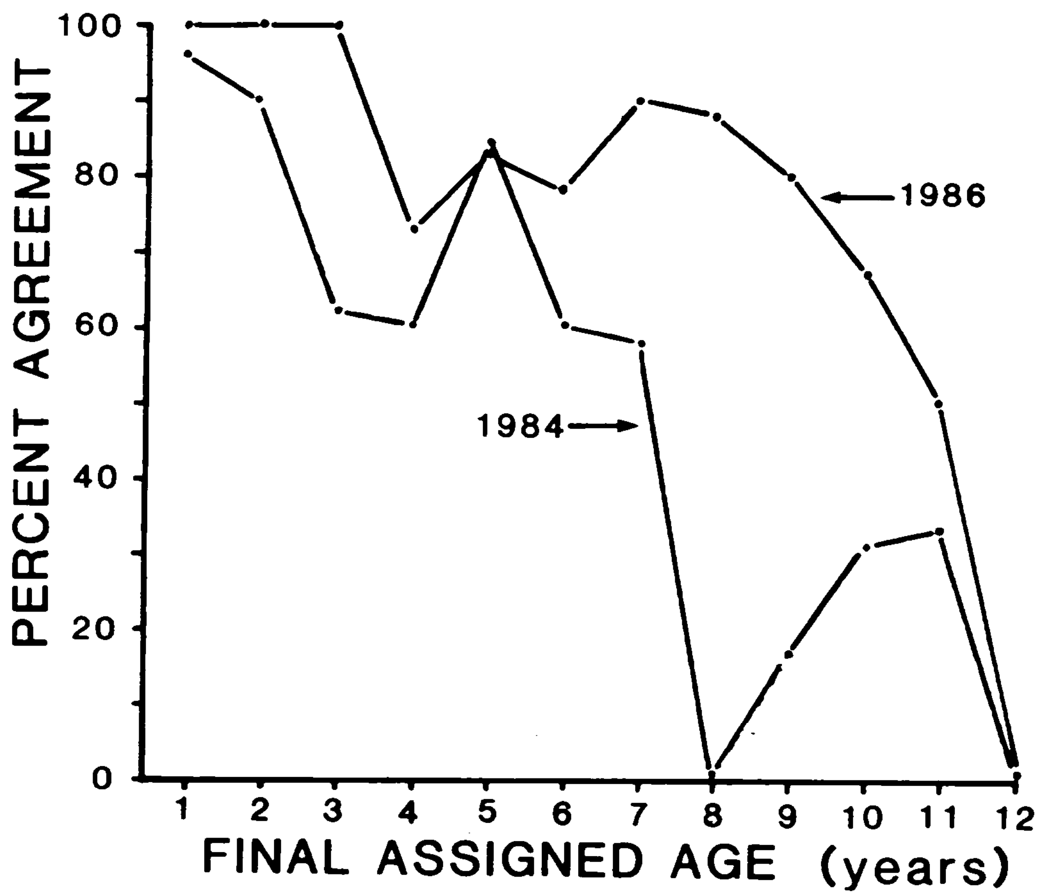

Figure 11. Agreement between first age and final assigned age of walleye from scale readings made in 1984 and 1986, John Day Reservoir.

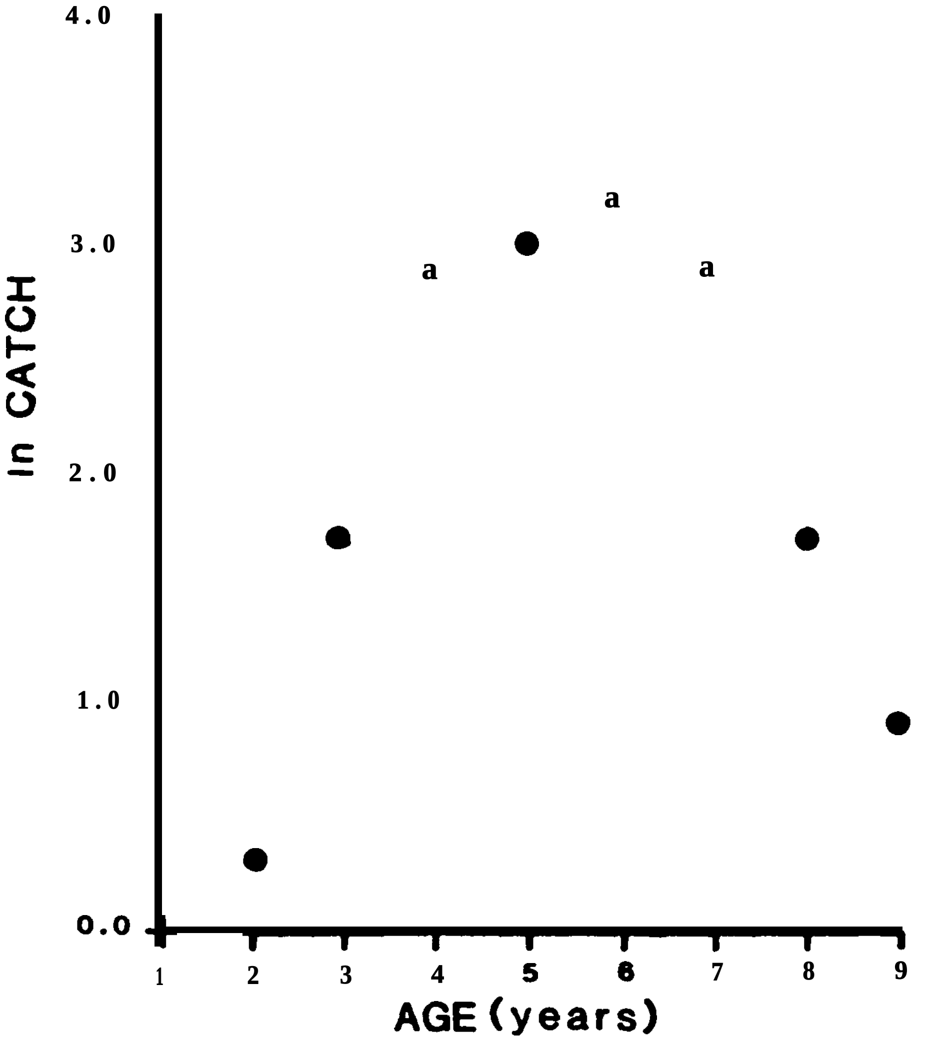

Figure 12. Catch curve of walleye in John Day Reservoir 1983-86.

Table 12. Mortality estimated from cohort analysis of effort-adjusted age frequencies for walleye sampled with gillnets in John Day Reservoir 1984-86.

Year Class	Age classes included in estimates	Mortality
1983	2-3	0.15
1982	3-4	0.13
1981	3-5	0.29
1980	4-6	0.21
1979	5-7	0.33
1978	6-8	0.32
1977	7-9	0.48

Table 13. Mortality estimated from recoveries of marked walleye in years following marking in John Day Reservoir 1983-86.

Year Marked	Number Marked	Year Recovered 1984	1985	1986	Mortality
1982	175	4	4	2	0.34
1983	628	55	11	2	0.81
1984	651	--	39	22	0.43

Table 14. Exploitation of walleye in John Day Reservoir 1984-86.

Year	Tag return data	Harvest population data
1984	0.07	0.02
1985	0.05	0.01
1986	0.02	0.02

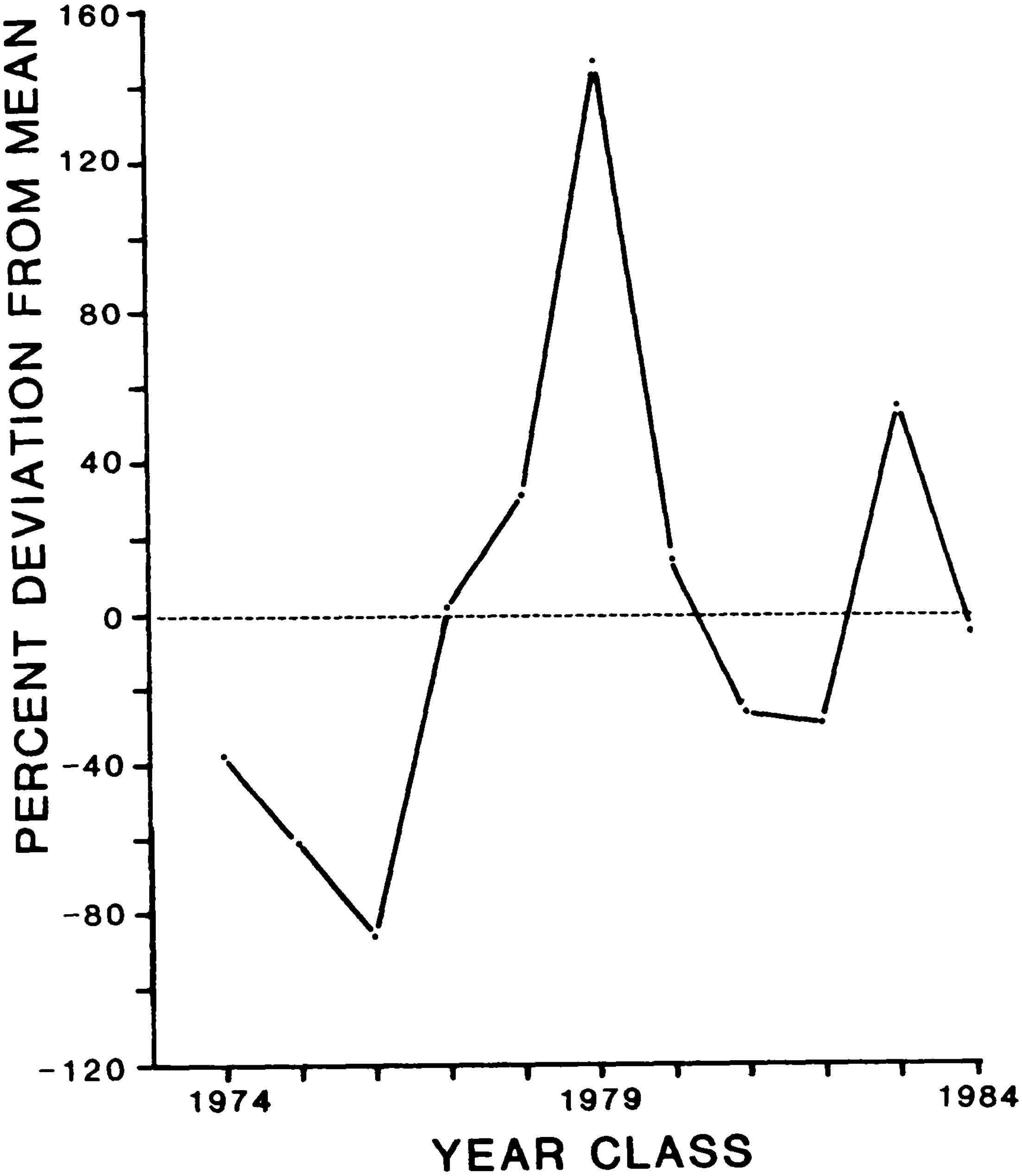

Figure 13. Relative year class strength of walleye in John Day Reservoir, 1974-84.

fish in August (Figure 14). Differences between areas varied monthly. These between-month differences were significant for 200-250 mm fish ($F = 3.7$; $df = 12,865$; $p < 0.01$) and >250 mm fish ($F = 2.9$; $df = 12,865$; $P < 0.01$). Fish in both size groups were apparently most abundant in the forebay, Arlington, and Irrigon areas depending on month.

Smallmouth bass were seldom recaptured in areas other than where released (Table 15). However, movements up to 40 km were observed (Figure 15). Also, 28% of the fish that were recaptured in the same area as released were taken at sites other than their release sites. In addition some exchange of fish was noted between John Day River and the forebay. Eleven percent of the recaptures of fish released in those areas had moved between forebay and river.

Table 15. Numbers of marked smallmouth bass released and recaptured by area, John Day Reservoir, 25 March to 1 September 1986. Numbers in parentheses are the subset of fish recaptured in the same site where released.

Area released	Number released	Area recaptured						
		F	R	A	C	I	M	B
Forebay (F)	330	84(57)	--	--	--	--	--	--
Rock Creek (R)	21	--	1					
Arlington (A)	410	2	--	69(50)	1	--	--	--
Crow Butte (C)	214	--	--	--	12	1	1	
Irrigon (I)	529	--	--	--	1	64(52)	1	--
McNary tailrace (M)	I33	--	--	--	--	1	23(22)	--
Boat restricted zone (B)	2	--	--	--	--	--	1	0

Abundance

We estimated 38,459 smallmouth bass at least 200 mm in length were present in John Day Reservoir in 1986 (2.0 fish per hectare). Ninety-five percent confidence limits ranged from -32% to +42% The 1986 estimate of smallmouth abundance was 27% larger than an estimate calculated for 1985 (Table 16). Estimates for other years were not comparable because of incomplete sampling. Assumptions regarding mixing, estimated angler harvest, and recruitment because of growth during sampling were important in estimates of smallmouth bass abundance (Table 17). Restricting the duration of marking and recapture had some effect on the abundance estimate but also resulted in a large loss of precision. Separating estimates by size class to accommodate size related vulnerability had little effect on the final estimate.

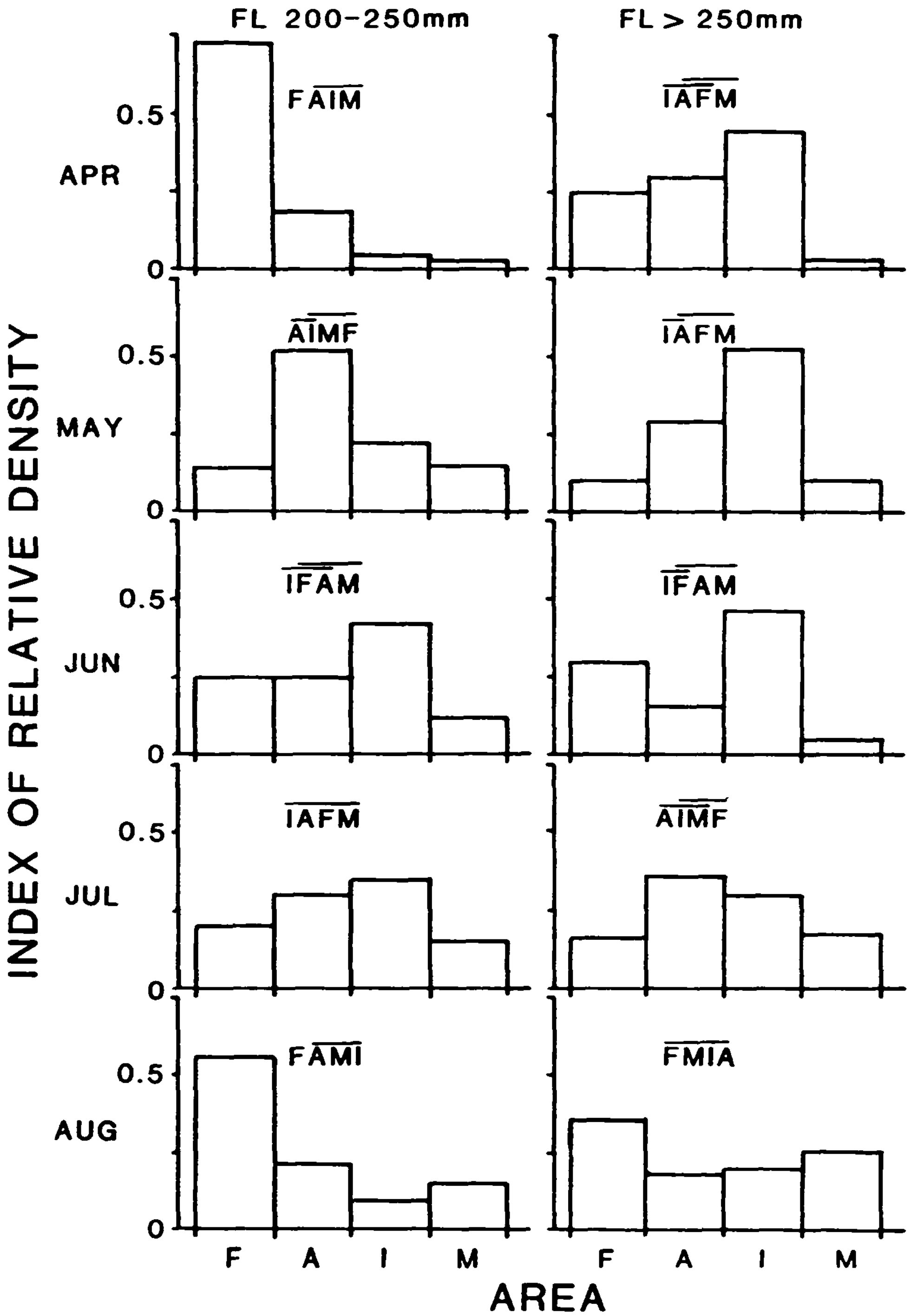

Figure 14. Indexes of smallmouth bass density in John Day Reservoir based on catch per unit effort. Areas include forebay (F), Arlington (A), Irrigon (I), McNary tailrace (M), and McNary boat-restricted zone (B). Results of tests for pairwise differences are included for each month and size class.

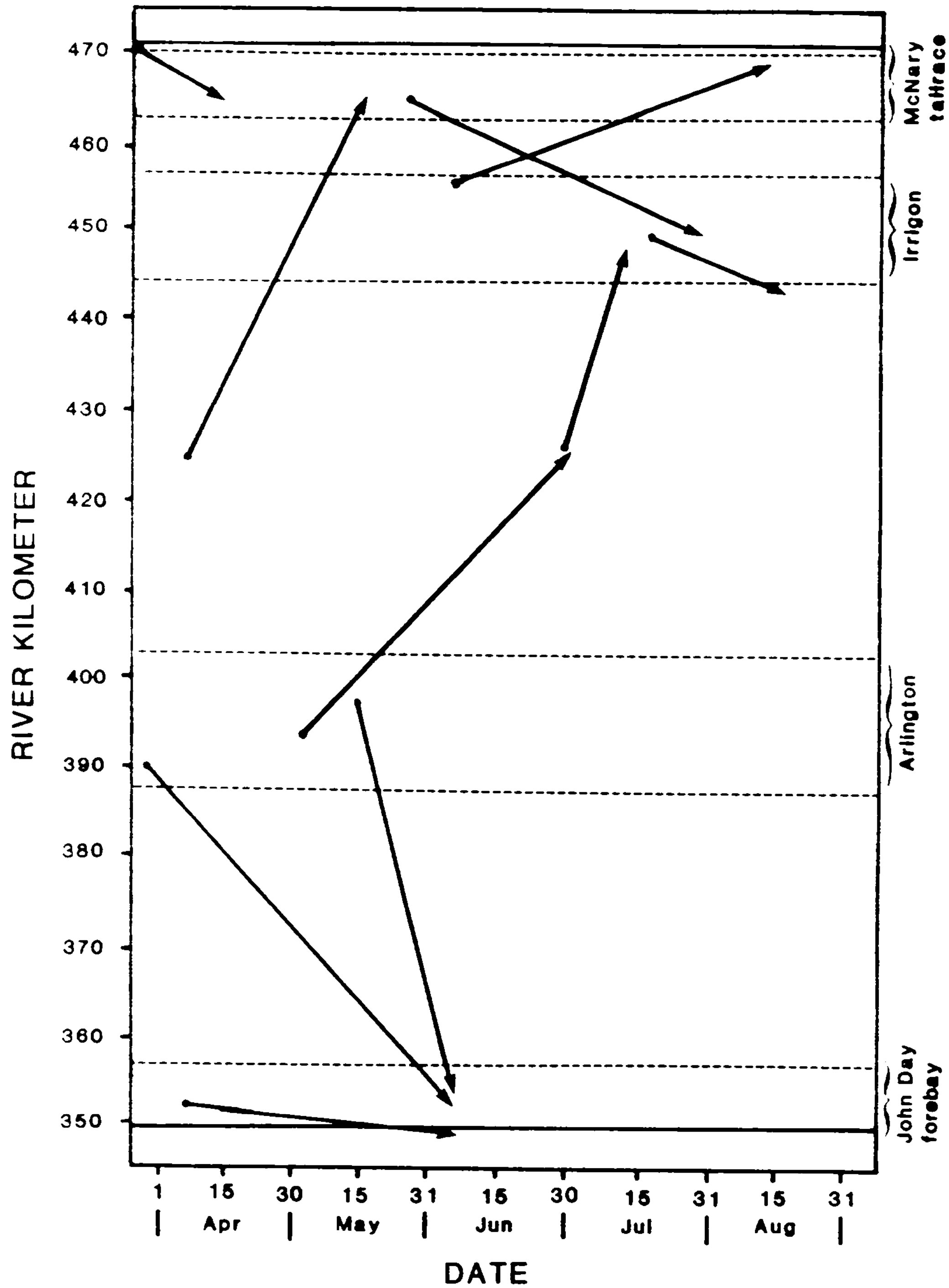

Figure 15. Movement of marked smallmouth bass recaptured in areas other than where marked in John Day Reservoir, 1986. Areas sampled are indicated by brackets. Dot indicates date and location of tagging. Tip of arrow indicates date and location of recovery.

Table 16. Number of smallmouth bass in John Day Reservoir, 1984-86. Estimates were based on an assumption of no mixing outside sampled area and were adjusted for estimated angler harvest and recruitment due to growth during sampling.

Year	Estimated abundance	95% Confidence Limits	
		Lower	Upper
1983[a]	8,678	4,625	21,326
1984[b]	13,384	10,192	19,024
1985	30,387	18,734	47,681
1986	38,459	26,047	54,566

a 1983 estimate was wt adjusted for angler harvest in the lower reservoir, incompletely covered the Irrigon area, and ignored the area between the forebay and Crow Butte later represented by the Arlington sample.

b 1984 estimate was wt adjusted for angler harvest in the lower reservoir and incompletely covered in the Irrigon area.

No long term effects of marking on fish condition could be discerned from comparisons of survival of marked and unmarked smallmouth bass. Mortality was 1% in both groups.

Harvest

Anglers harvested an estimated 7,382 unmarked smallmouth bass in the portion of the reservoir surveyed. Angler harvest of marked fish was estimated at 98 based on the angler survey and 118 based on voluntary angler returns. Approximately two thirds of these fish were taken in the lower reservoir (Table 18) and most of the lower reservoir harvest occurred in the John Day River. Harvest varied seasonally in the upper reservoir with most fish being taken in April and May. Similar harvest was seen in the lower reservoir in all months. Anglers harvested smallmouth bass between 200 and 475 mm in length, and the average fish was larger in the upper (312 mm) than the lower (301 mm) reservoir (Appendix Table C-11).

Estimated harvest in the upper reservoir was much larger in 1986 than estimates in previous years (Table 18). Estimated harvest in the lower reservoir was greater than in 1985. Estimates of removals of marked fish by anglers based on voluntary returns were generally greater than estimates based on the angler survey. The exception was the lower reservoir where sample sizes were larger than elsewhere.

Table 17. Alternative estimates of smallmouth bass abundance in 1986, based on various adjustments to accomodate assumptions. Effects of changing assumptions on magnitude and precision of abundance estimate of smallmouth bass were calculated relative to an estimate made using all areas, times, and sizes of smallmouth bass pooled.

Adjustment	Related Assumptions	Abundance		Confidence Limits		
		tstimate	change	Estimate		changed
None	Mixing, equal vulnerability, closure	15,331	--	-14%	+17%	--
Expand subarea estimates	No mixing of marks	38,567	+156%	-28%	+35%	-103%
Separate estimates by subarea[a]	Limited mixing of marks	12,506	-18%	-29%	+38%	-115%
Separate estimates by size class	Size-related vulnerability	15,221	-1%	-20%	+24%	-42%
Account for harvest	Removals significant	18,904	+23%	-141,	+17%	0%
Increase size limits with time	Recruitment due to growth	11,214	-27%	-15%	+17%	-4%
Restrict duration of marking and recapture	Immigration, emigration, recruitment, mortality	12,445	-19%	-19%,	+23%	-36%
Expand subarea, account for harvest and increase size limits with time	No mixing, significant removals, size-related vulnerability	38,459	+151	-32%,	+42%	-138%

a *Average* of upper *and lower limit percentage changes, minus sign indicates widening* of confidence *intervat.*

Table 18. Estimated harvest of smallmouth bass by anglers from portions of John Day Reservoir, 1983-86. Estimates include the period June through August in 1983 and April through August in 1984 througn 1986.

Year, fishing area, method of estimation	Marked	Unmarked
1983		
Lower area:		
Voluntary returns[a]	14	0
Upper area:		
Effort x CPUEb,c	0	336
Voluntary returns"	16	0
1984		
Lower area:		
Voluntary returns[a]	114	0
Upper area:		
Effort x CPUE[b,d]	42	541
Voluntary returns[a]	67	0
1985		
Lower area:		
Effort x CPUE[b,e]	151	4,003
Voluntary returns[a]	138	0
Upper area:		
Effort x CPUE[b]	4	294
Voluntary returns[a]	33	0
1986		
Lower area:		
Effort x CPUE[b]	72	4,945
Voluntary returns[a]	58	0
Upper area:		
Effort x CPUE[b]	26	2,437
Voluntary returns[a]	60	0

a Expanded from observed for 50% wnreporting mte, includes areas beyond where anglers were surveyed.
b Catch per unit effort estimated from angler survey.
c 1983 angler survey was limited to McNary tailrace.
d Upper reservoir was expanded to area above Paterson in 1984.
e Lower reservoir including John Day River and forebay was added to angler survey in 1985.

Age and Growth

Ages of smallmouth bass in our samples ranged from 1 to 11 years in the lower reservoir and from 1 to 12 years in the upper reservoir. Growth from backcalculated length-at-age was faster in the upper reservoir although lower reservoir fish reached a larger maximum size (Figure 16).

Percent reader disagreement between first age determination and final assigned age of smallmouth bass was variable but relatively good until approximately age 8 (Figure 17).

Mortality

Catch curves generated from the adjusted age composition for smallmouth bass (Appendix Tables E-10 and E-12) had smooth right limbs (Figure 18). Estimates of mortality using catch curves *were* 0.39 in the upper reservoir and 0.36 in the lower reservoir. Mortality estimated by cohort analysis was highly variable in both parts of the reservoir (Table 19) ranging from 0 to 0.55. The means of the individual estimates were 0.26 in the upper reservoir and 0.39 in the lower reservoir. Mortality estimated by sequential annual tag recovery was possible only by pooling data for the entire reservoir. A reasonable estimate was not possible from the limited recoveries available for 1982 marks (Table 20). Estimates for the other two years (0.70 in both years) were much higher than that from other methods.

Exploitation of smallmouth bass approximated from tag returns (Table 21) (Appendix Tables F-3 and F-4) averaged 0.45 in the lower reservoir and 0.26 in the upper reservoir. Exploitation approximated from harvest and population estimates in the upper reservoir, was 0.24, but in the lower reservoir was 0.94.

Comparison of total mortality with exploitation estimates did not provide a consistent estimate of natural mortality for smallmouth bass since exploitation exceeded estimated mortality in most cases. Instantaneous natural mortality, estimated using the method of Pauly (1980), was 0.42 in the lower reservoir and 0.31 in the upper reservoir.

Year-class Strength

Year-class strength of smallmouth bass was highly variable (Figure 19). Trends among reservoir areas were similar from 1976 to 1984. However, the 1985 year class was strong in the upper reservoir and weak in the lower reservoir. Year-class strength in both reservoir areas was most highly carrel ated with spring and summer water temperatures (lower reservoir, r = 0.95; upper reservoir, r = 0.53) and *reservoir* flows (lower reservoir, r = -0.77, upper reservoir, r = -0.54).

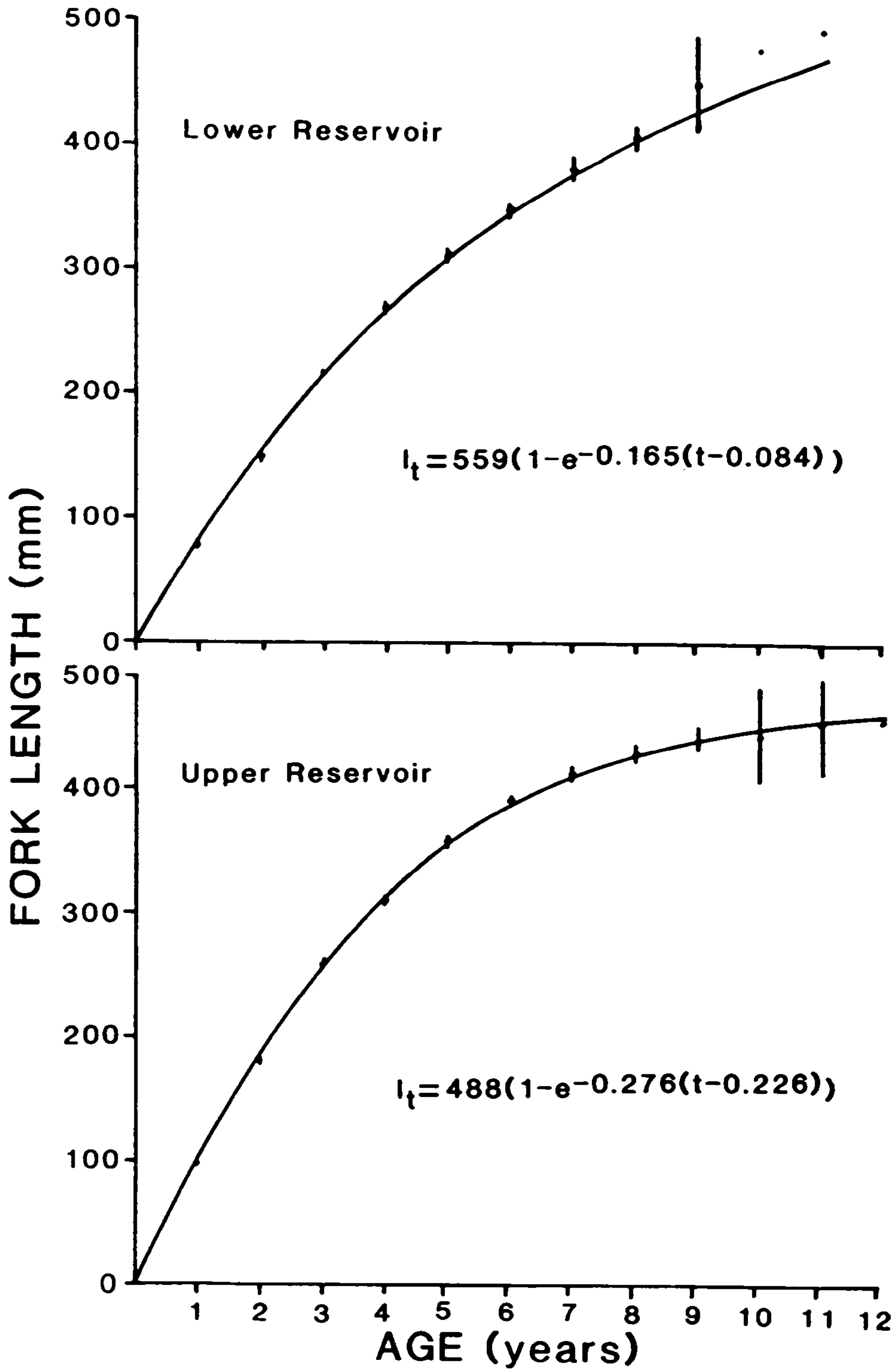

Figure 16. Mean backcalculated fork lengths with ±95% confidence intervals and with growth curve predicted by Von Bertalanffy equation for smallmouth bass, sexes combined, John Day Reservoir, 1982-86.

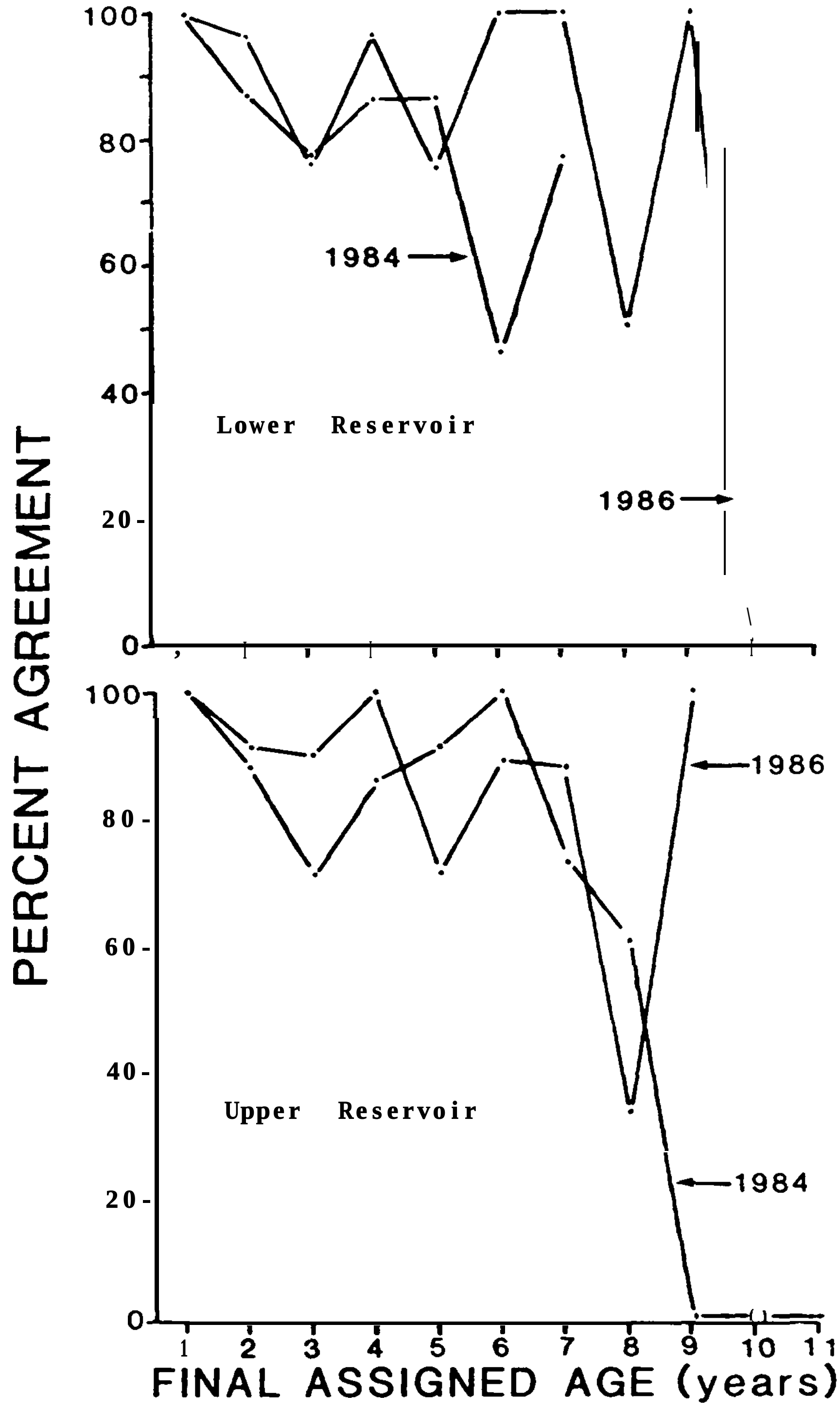

Figure 17. Agreement between first age and final assigned age of smallmouth bass from scale readings made in 1984 and 1986, John Day Reservoir.

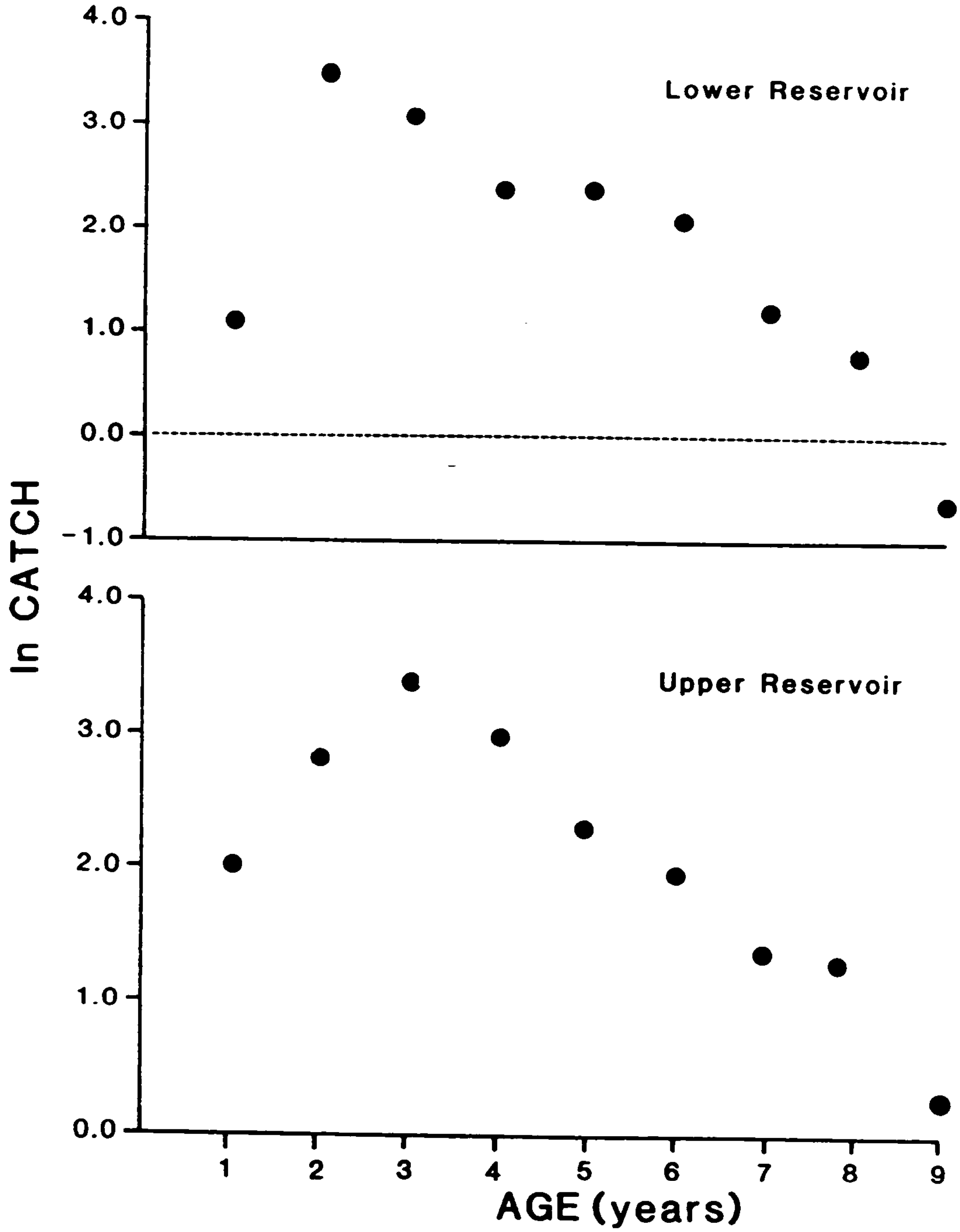

Figure 18. Catch curves of smallmouth bass in lower and upper John Day Reservoir 1983-86.

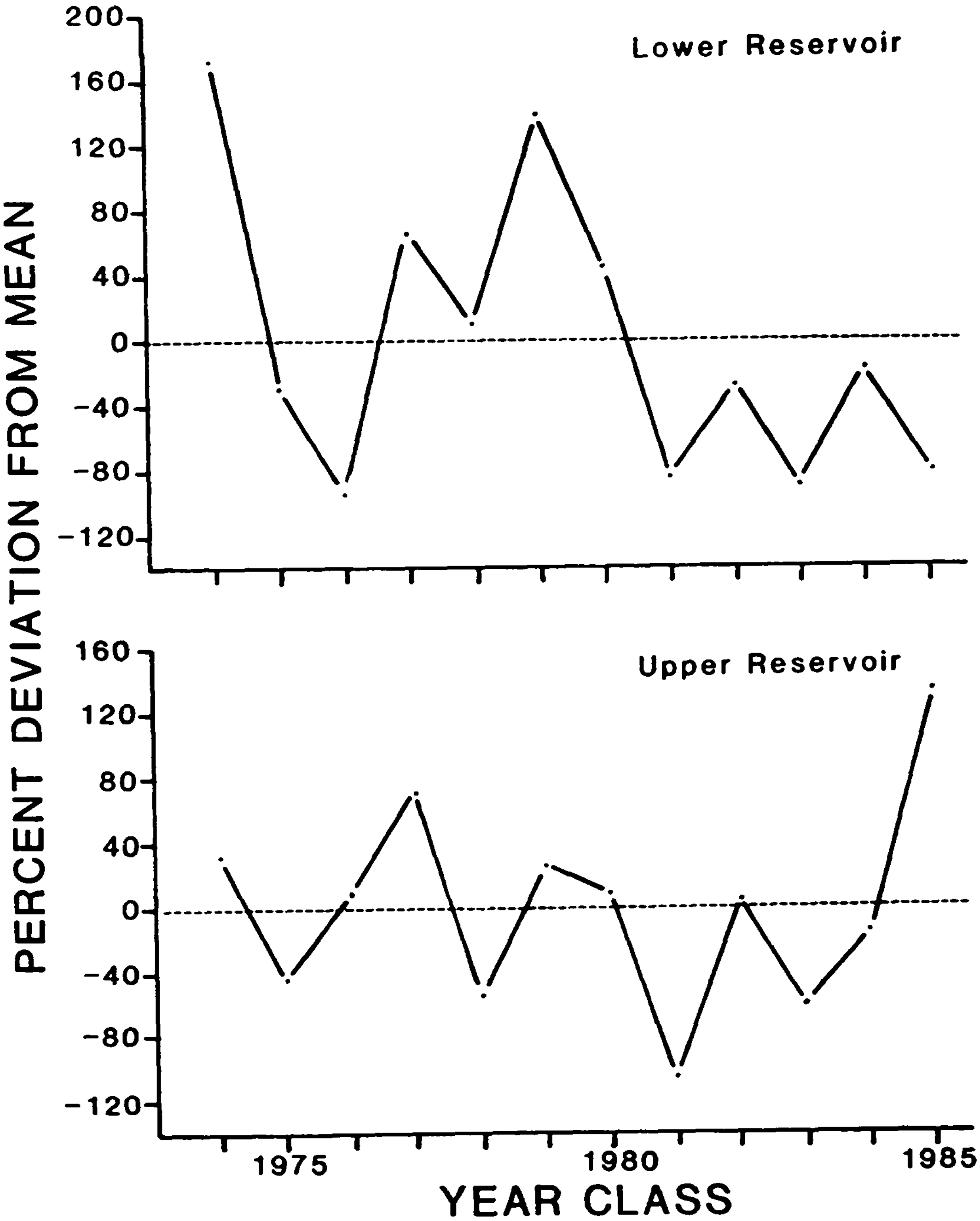

Figure 19. Relative year-class strength of smallmouth bass in John Day Reservoir, 1974-85.

Table 19. **Mortality estimated from cohort analysis of expected age frequencies of smallmouth bass adjusted for electrofishing sampling effort in lower and upper John Day Reservoir,** 1984-86.

Year **Class**	**Age classes included in estimates**	**Mortality**	
		Lower	Upper
1982	2-4	0.31	--
1981	3-5	0.23	0.14
1980	4-6	0.49	0.48
1979	5-7	0.47	0.36
1978	6-8	0.55	0.24
1977	7-9	0.31	0.14
1976	8-9	--	0.46

Table 20. Mortality estimated from recoveries of marked smallmouth bass in years following marking in John Day Reservoir, 1984-86.

Year Marked	**Number Marked**	**Year Recovered**			**Mortality**
		1984	1985	1986	
1982	121[a]	2	5	4	--
1983	546	43	7	45	0.70
1984	1227	--	147		0.70

a Records for 1982 are incomplete and more fish may have been marked.

Table 21. **Exploitation of smallmouth bass in for John Day Reservoir 1984-86.**

Year	**Lower Reservoir**		**Upper Reservoir**	
	Tag return data	**Harvest population data**	**Tag return data**	**Harvest population data**
1984	0.35		0.40	0.29
1985	0.52	0.94	0.20	0.07
1986	0.47	0.94	0.19	0.37

Channel Catfish

Distribution and Movements

Channel catfish were distributed throughout the reservoir during our entire April-August sampling season (Figure 20). No difference in relative abundance was seen among forebay, Arlington, Irrigon and McNary tailrace (excluding BRZ) sampling areas. Channel catfish densities in the BRZ below McNary Dam appeared relatively high since 28% of the sample was collected there. Density in the BRZ could not be compared with density in other areas because many of the fish were collected with large-mesh gillnets used only in that area.

Movements between McNary tailrace and Irrigon areas by channel catfish were observed (Table 22). The extent of movements beyond Irrigon could not be described because of limited recaptures.

Table 22. Numbers of marked channel catfish released and recaptured by area, John Day Reservoir, 25 March-l September 1986. Numbers in parentheses are the subset fish recaptured in the same site where released.

Area released	Number released	Area recaptured				
		F	A	I	M	B
Forebay (F)	58	0	--	--	--	--
Arlington (A)	28	--	0	--	--	--
Irrigon (I)	71	--	--	0	2	--
McNary tailrace (M)	74	--	--	1	6(2)	--
Boat restricted zone (B)	8	--	--	--	--	0

Abundance

Channel catfish abundance in the McNary tailrace to Irrigon area was estimated at 5,351 fish (1.6 fish per hectare) based on four recaptures. Confidence intervals ranged from 1,477 (-72%) to 15,797 (+195%). If this estimate is expanded reservoir-wide based on relative area sizes, abundance would be an estimated 29,955 channel catfish.

Harvest

Anglers harvested no marked and an estimated 924 unmarked channel catfish from the lower reservoir and an estimated 10 marked and 25 unmarked channel catfish from the upper reservoir. Estimates of marks removed from the upper reservoir were based on voluntary returns because no marks were observed during angler interviews. Most of the catch in the lower reservoir occurred in late May and

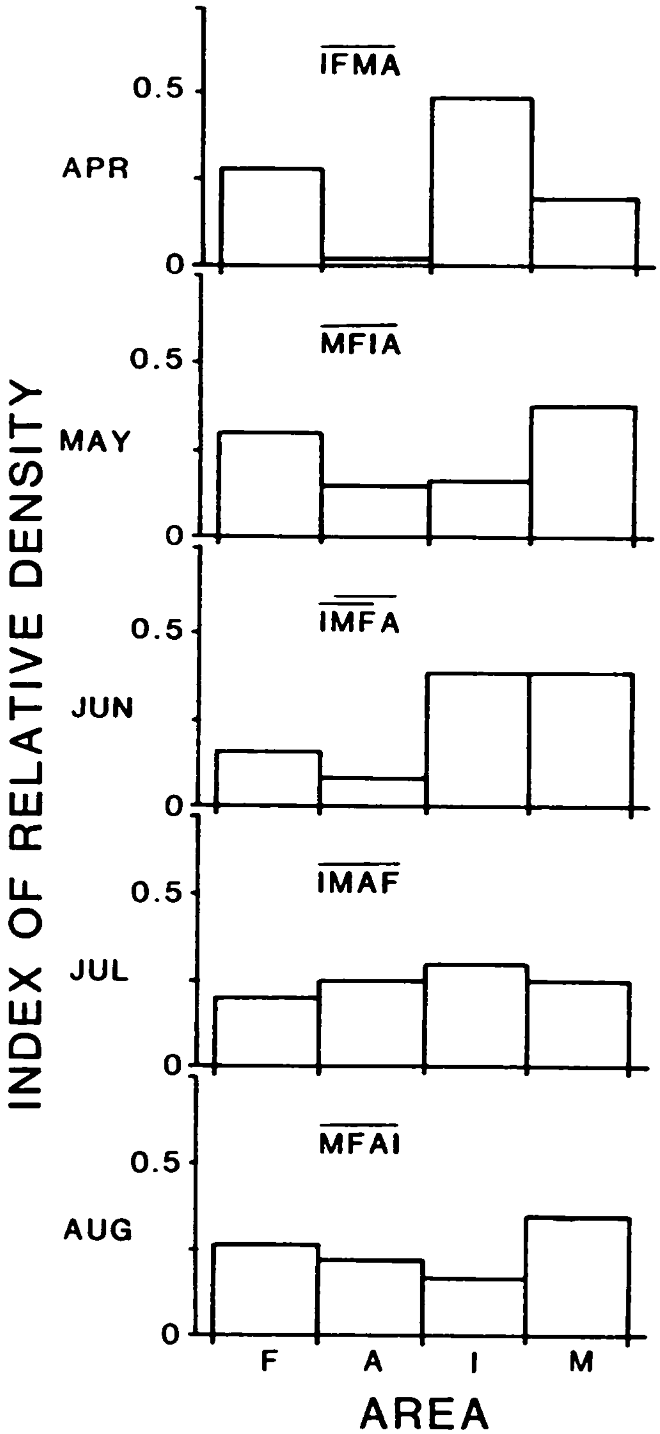

Figure 20. Indexes of channel catfish density in John Day Reservoir based on catch per unit effort. Areas include forebay (F), Arlington (A), Irrigon (I) and McNary tailrace (M). Results of tests for pairwise differences are included for each month.

June. Anglers harvested channel catfish ranging from ZOO to 600 mm in length. Average size of harvested channel catfish was 363 mm (N = 98) in the lower reservoir and 306 (N = 4) in the upper reservoir (Appendix Table C-11).

DISCUSSION

Northern Squawfish

Northern squawfish were not evenly distributed through the reservoir. Relative abundance based on CPUE varied by sampling area but was significantly higher in the BRZ just below McNary Dam than in any other area. If we assume that CPUE is directly proportional to actual density, northern squawfish density in the BRZ would have ranged from 6 to 30 times that in other parts of the reservoir.

Our data could be biased and may not accurately reflect the density of northern squawfish in the BRZ relative to other areas. Our sampling was limited to a single gear in that area, and we have no means of testing the basic assumption of equality and proportionality in the relation between CPUE and density. Although we cannot address these limitations of our data, concentration below a dam appears common. Other work indicates that concentrations of northern squawfish have consistently been found associated with other dams in the system (Sims 1979; Uremovich et al. 1980).

The uneven distribution of northern squawfish in the reservoir may have important implications in further work with predation. Consumption of salmonid prey by northern squawfish also appears to be much higher in the BRZ than in other parts of the reservoir (Poe and nine coauthors 1987). As a result, a disproportionately large part of northern squawfish predation on juvenile salmonids may occur in a small area associated with the dam (Rieman et al. 1987).

Northern squawfish was the most abundant of the four species we sampled in John Day Reservoir. Although we estimated 108,000 northern squawfish present in 1986, that estimate is relatively imprecise and vulnerable to several assumptions. The most important assumption is that of the mixing of tagged and untagged fish throughout the population. Although our tag recoveries and previous radiotelemetry work show that northern squawfish are highly mobile, mixing undoubtedly was incomplete among sampling areas. Our estimate of abundance assuming mixing may be biased low. Alternative estimates assuming no mixing (528,000) and very limited mixing (235,000) probably are biased high because tagged fish mixed freely and estimates from adjacent areas overlapped. Although we believe our original estimate best represents the 1986 population, the alternative estimates are useful as bounds representing extremes possibly owing to failure in the assumption of mixing. Our analysis suggests that the estimator is robust to the other assumptions examined. Error in the estimate from failure of assumptions regarding removals, recruitment, and size related vulnerability is probably small.

The estimated density of northern squawfish (5.6 per hectare >250 mm) is less than that estimated in Lake Washington (approximately 15 per hectare) (Bartoo 1977).

We got inconsistent estimates of mortality for northern squawfish over all ages and among methods. Catch curve and cohort analyses both suggest that mortality may increase with age over the range of 0.15 to 0.50. The tagging estimate was higher (0.60) but may berepresentative only of older fish. An estimated average mortality over all ages of 0.24 (from both catch curves and cohort methods) is equal to that estimated for northern squawfish in Lake Washington(Bartoo 1977) and is similar to natural mortality predicted from relations of growth and temperature (0.24-0.25).

Estimates of mortality and year-class strength represent our best approximation but should be used cautiously. Estimates of mortality and year-class strength are based on age structure in the population and may be biased by problems in aging. The subjectivity evident in our analysis of age agreement shows that error is certainly possible, but the error cannot be quantified because we have no independent method of age confirmation. Estimates do provide a useful starting point for further analysis planned with the predation model (Rieman et al. 1987).

The variability in year-class strength'suggests that the northern squawfish population should fluctuate in abundance through time. Although our abundance estimates are relatively insensitive because of a lack of precision, our data do suggest that abundance increased over the period of the study. This trend in estimates might reflect an upward trend in recruitment in recent years.

Little work has been devoted to understanding recruitment of northern squawfish. Hjort et al. (1981) suggested that physical habitat may influence distribution and relative abundance. Beamesderfer (1983) documented distinct physical habitat preferences. We felt that variables that influence physical habitat (such as flow) might also play a role in recruitment, and we did find some correlation of flow and temperature with year-class strength. Our data also suggested that recruitment of walleye may be negatively associated with recruitment of northern squawfish in a given brood year. Because walleye grow rapidly and are piscivorous in the first year (Palmer and thirteen coauthors 1986), predation may be an important regulator. Our data cannot be considered strong evidence of such interaction. Aging of both species was subjective which could have resulted in some error in the descriptions of year class strength. In addition, correlation does not necessarily indicate that a cause-and-effect relationship exists.

The importance of interaction between walleye and squawfish may warrant further work. Variation in year-class strength in northern squawfish is important in consideration of predation. The variation should result in variation in the abundance of predators and in the relative size structure of the population. Together these changes could strongly influence the total number of prey consumed and the magnitude of mortality experienced by migrating juvenile salmonids

(Rieman et al. 1987). Factors that influence recruitment of northern squawfish could play a significant role in salmonid management.

Walleye

CPUE was suitable for describing differences in relative abundance of walleye among reservoir areas despite low and variable catch rates. Significant differences among areas could be identified, a consistent trend could be followed and similar patterns were observed previously among radiotagged walleye (Nigro et al. 1985). Changes in distribution were consistent with those reported in other walleye populations. Movement of walleye down-reservoir after April probably corresponded to the completion of spawning. Colby et al. (1979) report walleye typically spawn from March to May and disperse to summer feeding grounds shortly after spawning.

Walleye were the least abundant predator in John Day Reservoir in 1986. Walleye density in John Day Reservoir was also low relative to other systems. No density less than 7 fish per hectare is reported in a summary of the walleye literature by Colby et al. 1979. However, walleye numbers may have been depressed during study years. Recruitment is highly variable and has been poor since 1979. The strong 1979 year class apparently comprises the bulk of the walleye population, which would be expected to decline each year since 1979 as fish died and were not replaced by new recruits. Our abundance estimates did not support a decline, but changes in sampling and low precision may have obscured any trends in abundance among years that might have been evident from our data. A declining walleye population could explain decreases in angler harvest of walleye from 1983 to present.

Assumptions regarding mixing of marked and unmarked fish and recruitment because of growth during sampling were critical in estimates of walleye abundance. A restricted sampling duration had to be adopted for walleye because 1985 radiotelemetry data indicated a large segment of the population was unavailable to sampling after June when walleye dispersed from the upper reservoir following spawning. We were unable to investigate the bias caused by the assumption that marked and unmarked fish mix freely from March through June. The number of recaptures was inadequate for anything other than a pooled estimate, but the pooled estimate would be conservative if some walleye that occur below Paterson never enter sampling areas.

Mortality estimates for walleye were inconsistent. Maximum estimates ranged from 0.48 to 0.67 depending on method. The cohort analysis suggests that mortality may increase with age. The dome in the catch curve may be indicative of a similar response but may also be the result of bias because of variation in year-class strength (Ricker 1975). Mortality has been observed to increase with age in other populations (Colby et al. 1979). Natural mortality predicted from growth and temperature was also lower than that estimated from total mortality and exploitation, suggesting that with limited exploitation average mortality for all ages could be lower than 0.60. We believe that 0.67 represents the maximum mortality that occurred in any portion of the walleye population, and that lower mortality is likely, particularly in younger fish. Mortality between 0.40 and 0.55 are commonly reported in the literature (Colby et al. 1979). Fishing appears to have been a minor part of total mortality in the population.

Small mouth Bass

Describing differences in smallmouth bass density between areas based on CPUE was questionable. According to catch rates based on electrofishing, distributions of smallmouth bass varied monthly, and in various months fish were most abundant in the forebay, Arlington, and Irrigon areas. This is inconsistent with density based on mark and recapture abundance estimates. According to abundance estimates, smallmouth bass density was greatest in the forebay (6.0 fish per hectare) followed by Irrigon (2.8 fish per hectare), Arlington (1.1 fish per hectare) and McNary tailrace (0.6 fish per hectare). In addition, a distribution that changes with month implies that the fish move among areas. However, tagging data indicates smallmouth bass move very little. Differences in relative abundance between areas based on CPUE were likely a result of sampling variability and inshore-offshore movements rather than a reflection of real differences.

Abundance of smallmouth bass in John Day Reservoir was between that of northern squawfish and walleye. As with walleye, smallmouth bass density was lower than reported elsewhere. Carlander (1977) reports no density under 16 smallmouth bass per hectare.

Smallmouth bass abundance (38,459) is probably overestimated. Assumptions regarding the degree of mixing of marked and unmarked fish were critical in estimating population size. The best estimate was based on an assumption of no mixing outside areas sampled because few smallmouth bass were recaptured in areas other than where tagged. The fact that some fish moved means that this assumption was not met. Estimates based on assumptions of no mixing and of complete mixing represent the extremes of abundance estimates based on variation in the degree of mixing.

Mortality estimates for smallmouth bass were also variable (range 0.26-0.65). However, we believe that the estimate based on mark recoveries is biased. Mark recoveries for smallmouth bass relied heavily on angler tag returns rather than primarily on project sampling as with other species. Tag loss could not be recognized through secondary marks as with project sampling. Tag loss estimated from our data may exceed 5% in the first year (NigroI et al. 1985) and 30% in subsequent years (unpublished data) and could easily account for differences observed in estimates. Catch curves were relatively smooth over the range of ages considered in the estimates, but individual estimates from cohort analysis ranged

0-0.55. We have no reason to expect any bias in the catch curve estimates. We believe they represent the best estimates of mortality for smallmouth bass in John Day Reservoir.

Exploitation appears to have been a major cause of mortality in smallmouth bass. Estimates based on tag recoveries can account for 82 to 100% of the estimated total mortality. Estimates of exploitation based on tag recoveries were probably more reliable than those based on harvest and population data because harvest estimates do not include the entire reservoir. Areas between the forebay and Paterson were not included in the angler survey because indications were that angler effort in those areas was light. Angler tag returns from unsurveyed areas indicate effort was greater than first believed.

The data suggest that natural mortality may be much lower than predicted based on growth and temperature.

Channel Catfish

Abundance of channel catfish may be comparable to that of walleye and smallmouth bass. However, estimates of channel catfish were not as well defined as were those of other predators. Examination of the effects of varying assumptions on the estimate were precluded by the low number of recaptures outside the Irrigon to McNary areas. Reservoir-wide channel catfish abundance could only be estimated by assuming the Irrigon and McNary population was discrete and that density of channel catfish was similar in all portions of the reservoir. Observed movements in the upper pool indicate channel catfish may be relatively mobile. Therefore, occurrence of discrete local populations would be unlikely. Relative CPUE's imply similar densities occur reservoir-wide, but low catch rates may have obscured differences. The power of tests for differences was probably quite low. Mixing of fish into or out of the upper reservoir would inflate the reservoir-wide estimate. Error in estimation would result if channel catfish density was different in other areas.

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APPENDIX A

Sampling Periods, Effort, and Catch,

Appendix Table A-l. Dates corresponding to sampling periods, 23 March - 1 September 1986.

Sampling period	Beginning date	Ending date
7	23 March	5 April
8	6 April	19 April
9	20 April	2 May
10	4 May	17 May
11	18 May	31 May
12	1 June	14 June
13	15 June	28 June
14	29 June	19[a] July
15	29 July	2 August
16	3 August	16 August
17	17 August	1 September

a Period is three weeks in length.

Appendix Table A-2. Hours of sampling effort in John Day Reservoir, 23 March-1 September 1986.

Area, gear	Sampling Period 7	8	9	10	11	12	13	14	15	16	All
Forebay:											
Bottom gill net (sm)	9	24	24	24	24	24	26	26	23	23	227
Trap net	0	135	136	182	112	179	180	184	137	135	1380
Trap net lead	0	159	92	183	135	180	181	185	137	135	1387
Electrofisher	1	5	6	5	6	6	6	13	17	7	72
Forebay to Arlington:											
Bottom gill net (sm)	30	0	0	0	0	0	0	0	0	0	30
Electrofisher	7	0	0	0	0	0	0	0	0	0	7
Arlington:											
Bottom gill net (sm)	12	25	24	24	24	24	24	24	25	27	233
Trap net	0	159	274	247	205	204	274	271	271	275	2180
Trap net lead	0	137	275	270	206	204	275	271	271	276	2185
Electrofisher	2	5	5	6	6	7	6	10	21	8	76
Angling	0	0	0	1	0	0	0	0	0	0	1
Arlington to Irrigon:											
Bottom gill net (sm)	20	0	0	0	0	0	0	0	0	0	20
Bottom gill net (lg)	0	0	0	0	0	0	0	0	5	0	5
Electrofisher	3	0	0	0	0	0	0	10	0	0	13
Irrigon:											
Bottom gill net (sm)	13	24	24	24	27	25	24	25	25	24	235
Bottom gill net (lg)	0	0	2	0	0	0	0	106	99	0	207
Trap net	46	214	261	259	217	223	281	278	216	255	2250
Trap net lead	46	214	286	282	218	271	282	279	216	278	2372
Electrofisher	1	6	6	5	6	6	6	23	21	6	86
McNary tailrace:											
Bottom gill net (sm)	24	19	24	24	23	25	25	21	21	21	227
Bottom gill net (lg)	3	6	7	3	3	1	1	72	3	9	108
Trap net	71	189	185	187	142	146	184	185	186	136	1611
Trap net lead	71	190	186	187	141	144	185	186	186	137	1613
Electrofisher	1	5	4	5	6	6	5	22	5	5	64

Appendix Table A-2. Continued

Area, gear	Sampling Period										
	7	8	9	10	11	12	13	14	13	16	All
Boat Restricted Zone:											
Bottom gill net (sm)	0	0	0	9	1	0	0	2	2	3	9
Bottom gill net (lg)	0	14	9	6	10	13	11	78	0	10	154
Electrofisher	0	5	7		6	7	7	11	1	7	57
Angling	2	4	4	4	4	4	14	14	15	15	80
All:											
Bottom gill net (sm)	108	92	96	98	99	98	100	98	96	98	983
Bottom gill net (lg)	3	20	18	12	13	14	12	256	107	19	474
Trap net	117	697	856	875	676	752	919	918	810	801	7,421
Trap net lead	117	700	839	922	700	799	923	921	810	826	7,557
Electrofisher	15	26	28	27	30	32	30	89	65	33	375
Angling	2	4	4	4	4	4	14	14	15	15	80

Appendix Table A-3. Catch (and catch per hour) of northern squawfish, walleye, smallmouth bass, and channel catfish in John Day Reservoir, 23 March-1 September 1986.

Species, gear	Sampling Area							
	All	Forebay	Rock Creek	Arlington	Crow Butte	Irrigon	McNary tailrace	Boat restricted zone
Northern squawfish:								
Bottom gill net (sm mesh)	1,266 (1.29)	333 (1.46)	44 (1.49)	272 (1.17)	34 (1.70)	296 (1.25)	263 (1.15)	24 (2.66)
Bottom gill net (lg mesh)	268 (0.56)	--	--	--	0	22 (0.11)	17 (0.16)	229 (1.48)
Trap net	377 (0.05)	142 (0.10)	--	121 (0.06)	--	65 (0.03)	49 (0.03)	--
Trap net lead	724 (0.10)	135 (0.10)	--	168 (0.08)	--	251 (0.11)	170 (0.11)	--
Electrofisher	1,878 (5.00)	143 (1.96)	7 (0.97)	125 (1.65)	24 (1.86)	92 (1.08)	120 (1.87)	1,367 (23.70)
Angling	416 (5.13)	--	--	--	--	--	--	416 (5.20)
Angler survey	16	9	--	--	0	0	8	--
Total	4,945	762	51	686	58	726	627	2,036
Walleye:								
Bottom gill net (sm mesh)	162 (0.16)	0	0	11 (0.05)	1	67 (0.28)	82 (0.36)	1 (0.11)
Bottom gill net (lg mesh)	159 (0.33)	--	--	--	0	22 (0.11)	128 (1.18)	9 (0.06)
Trap net	53 (0.01)	0	--	3 (a)	--	17 (a)	33 (0.02)	--
Trap net lead	87 (0.01)	4 (a)	--	11 (0.01)	--	7 (a)	65 (0.04)	--
Electrofisher	100 (0.26)	0	0	18 (0.24)	9 (0.70)	7 (0.08)	63 (0.98)	3 (0.05)
Angling	0	--	--	--	--	--	--	0
Angler survey	41	2	--	--	16	16	10	--
Total	602	6	0	43	26	136	381	13
Smallmouth bass:								
Bottom gill net (sm mesh)	161 (0.16)	75 (0.33)	2 (0.07)	33 (0.14)	1 (0.05)	36 (0.15)	14 (0.06)	0
Bottom gill net (lg mesh)	6 (0.01)	--	--	--	--	5 (0.02)	1 (0.01)	0
Trap net	51 (0.02)	27 (0.01)	--	24 (0.01)	--	6 (a)	4 (b)	--
Trap net lead	13 (a)	3 (0.01)	--	4 (a)	--	4 (a)	2 (b)	--
Electrofisher	2,128 (5.66)	446 (6.12)	20 (2.76)	531 (7.00)	220 (3.44)	687 (8.07)	220 (3.44)	4 (0.07)
Angling	2 (0.02)	--	--	--	--	--	--	0
Angler survey	536	446	--	2	4	78	6	--
Total	2,897	987	22	594	225	816	247	4
Channel catfish:								
Bottom gill net (sm mesh)	164 (0.17)	59 (0.26)	0	29 (0.12)	0	30 (0.13)	46 (0.20)	0
Bottom gill net (lg mesh)	169 (0.36)	--	--	--	0	9 (0.04)	3 (0.03)	157 (1.01)
Trap net	115 (0.02)	16 (0.01)	--	12 (0.01)	--	49 (0.02)	38 (0.02)	--
Trap net lead	3 (a)	1 (a)	0	0	--	0	2 (a)	--
Electrofisher	15 (0.04)	3 (0.04)	0	1 (0.01)	1 (0.08)	3 (0.04)	7 (0.11)	0
Angling	2 (0.02)	--	--	0	--	--	--	2 (0.02)
Angler survey	95	90	--	0	0	3	2	--
Total	563	169	0	42	1	94	98	159

[a] *Catch per hour < 0.005.*

Appendix Table A-4. Catch per unit effort of northern squawfish in areas of John Day Reservoir, 1986. Units of effort are net hours (bottom gill net), net day (trap net) and 900 second current on time (electrofisher).

Size class, gear, area	April	May	June	July	August
250-400mm					
Gill net:					
Forebay	1.269	1.407	0.628	1.510	0.474
Arlington	1.652	0.796	0.477	0.610	0.499
Irrigon	0.743	1.241	1.402	0.539	0.673
McNary tailrace	0.589	1.052	1.260	0.752	0.284
Trap net:					
Forebay	1.238	1.715	**3.069**	**0.898**	1.247
Arlington	0.388	1.274	1.457	0.443	0.437
Irrigon	0.202	0.050	0.620	0.146	0.188
McNary tailrace	0.321	0.438	0.145	0.065	0
Electrofisher:					
Forebay	0.225	0.074	0.024	0.522	0.182
Arlington	0.163	0.083	0.100	0.242	0.042
Irrigon	0.136	0.625	0.480	0.085	0.042
McNary tailrace	0.243	0.786	0.837	0.130	0.250
Boat restricted zone	2.710	2.786	2.217	4.710	2.700
>400mm					
Gill net:					
Forebay	0.400	0.346	0.418	0.401	0.368
Arlington	0.312	0.324	0.227	0.366	0.363
Irrigon	0.206	0.453	0.639	0.160	0.090
McNary tailrace	0.259	0.536	0.516	0.047	0
Trap net:					
Forebay	0.796	0.327	**1.535**	0.225	0.535
Arlington	0.277	0.265	1.407	0.266	0.087
Irrigon	0.455	0.151	0.620	0.438	0.565
McNary tailrace	0.642	0.584	0.581	0.065	0.176
Electrofisher:					
Forebay	0.113	0.049	0.196	0.211	**0.091**
Arlington	0.081	0.125	0.040	0.155	0.375
Irrigon	0.068	0.075	0.327	0.024	0
McNary tailrace	0.091	0.119	0.186	0.052	0.050
Boat restricted zone	4.458	2.357	6.874	2.083	7.200

Appendix Table A-5. Catch per unit effort of walleye in areas of John Day Reservoir, 1986. Units of effort are net hours (bottom gill net), net day (trap net) and 900 second current on time (electrofisher).

Size class, gear, area	April	May	June	July	August
250-500mm					
Gill net:					
Forebay	0	0	0	0	0
Arlington	0	0.025	0.045	0	0.181
Irrigon	0.021	0.236	0.124	0.040	0.090
McNary tailrace	0.047	0.472	0.227	0.188	0.331
Trap net:					
Forebay	0	0	0	0	0
Arlington	0	0.053	0.050	0	0
Irrigon	0	0	0	0.049	0
McNary tailrace	0.064	0.292	0.073	0.129	0
Electrofisher:					
Forebay	0	0	0	0	0
Arlington	0.027	0.083	0.020	0.138	0.125
Irrigon	0.023	0	0.044	0.012	0
McNary tailrace	0.030	0.214	0.326	0.181	0
>500mm					
Gill net:					
Forebay	0	0	0	0	0
Arlington	0.022	0	0	0.049	0
Irrigon	0.041	0.512	0.309	0.020	0
McNary tailrace	0.118	0.279	0.062	0	0.047
Trap net:					
Forebay	0	0	0	0	0
Arlington	0	0	0.050	0	0
Irrigon	0	0.151	0.572	0	0
McNary tailrace	0.064	0.511	0.291	0	0
Electrofisher:					
Forebay	0	0	0	0	0
Arlington	0	0	0	0	0
Irrigon	0	0.025	0.022	0.012	0
McNary tailrace	0.061	0.071	0.047	0.013	0

Appendix Table A-6. Catch per unit effort of electrofishing for smallmouth bass, in areas of John Day Reservoir, 1986. Unit of effort is 900 second current on time.

Size class, area	April	May	June	July	August
200-250mm:					
Forebay	0.929	0.345	0.954	0.509	3.000
Arlington	0.217	1.333	0.960	0.725	1.125
Irrigon	0.045	0.575	1.700	0.849	0.458
McNary tailrace	0.030	0.357	0.488	0.363	0.750
>250mm:					
Forebay	0.957	0.567	1.272	0.286	0.955
Arlington	1.140	1.583	0.720	0.622	0.458
Irrigon	0.122	2.925	2.027	0.521	0.542
McNary tailrace	0.087	0.571	0.302	0.298	0.700

Appendix Table A-7. Catch per unit effort of channel catfish in areas of John Day Reservoir, 1986. Units of effort are net hours (bottom gill net), net day (trap net).

Gear, area	April	May	June	July	August
Gill net:					
Forebay	0.047	0.069	0.131	0.566	.0.842
Arlington	0	0.075	0.114	0.268	0.363
Irrigon	0.124	0.039	0.186	0.200	0.045
McNary tailrace	0	0.107	0.269	0.399	0.378
Trap net:					
Forebay	0.442	0.408	0.400	0	0
Arlington	0.055	0.053	0.050	0.266	0.350
Irrigon	0.354	0.201	1.192	0.389	0.471
McNary tailrace	0.578	0.438	1.018	0.194	0.705

Appendix Table A-8. Analysis of variance statistics for comparisons of catch per unit effort of northern squawfish between four areas of John Day Reservoir (forebay, Arlington, Irrigon and McNary tailrace), 1986. Analyses are based on gill net, trap net, and electrofishing observations.

Size class, month	Source	df	F	*P*
250-400 mm:				
April	Gear	2, 386	12.79	co.01
	Area	3, 386	1.79	0.15
	Interaction	6, 386	1.30	0.26
May	Gear	2, 406	10.75	co.01
	Area	3, 406	0.85	0.47
	Interaction	6, 406	3.20	co.01
June	Gear	2, 421	10.22	<O.Ol
	Area	3, 421	1.76	0.15
	Interaction	6, 421	7.06	<0.01
July	Gear	2, 537	25.89	<0.01
	Area	3, 537	11.57	co.01
	Interaction	6, 537	1.55	0.16
August	Gear	2, 198	8.06	<0.01
	Area	3, 198	3.08	0.03
	Interaction	6, 198	2.90	<0.01
>400 mm:				
April	Gear	2, 386	14.71	<0.01
	Area	3, 386	1.70	0.17
	Interaction	6, 386	0.97	0.44
May	Gear	2, 406	11.63	<0.01
	Area	3, 406	1.58	0.19
	Interaction	6, 406	0.70	0.65
June	Gear	2, 421	13.05	<0.01
	Area	3, 421	0.77	0.51
	Interacti on	6, 421	2.41	0.03
July	Gear	2, 537	4.93	<0 .01
	Area	3, 537	3.88	<0.01
	Interaction	6, 537	1.78	0.10
August	Gear	2, 198	1.18	0.31
	Area	3, 198	1.19	0.31
	Interaction	6, 198	1.63	U.14

Appendix Table A-9. Analysis of variance statistics for comparisons of catch per unit effort of walleye between four areas of John Day Reservoir (forebay, Arlington, Irrigon and McNary tailrace), 1986. Analyses are based on gill net, trap net, and electrofishing observations.

Size class, month	Source	df	*F*	*P*
250-500 mm:				
April	Gear	2, 386	0.03	0.97
	Area	3, 386	1.85	0.14
	Interaction	6, 386	0.34	0.92
May	Gear	2, 406	3.19	0.04
	Area	3, 406	8.29	<O.Ol
	Interaction	6, 406	1.68	0.12
June	Gear	2, 421	1.30	0.27
	Area	3, 421	6.16	<0.01
	Interaction	6, 421	1.20	0.30
July	Gear	2, 537	0.74	0.48
	Area	3, 537	5.46	co.01
	Interaction	6, 537	1.10	0.36
August	Gear	2, 198	5.79	co.01
	Area	3, 198	1.61	0.19
	Interaction	6, 198	1.83	0.10
>500 mm:				
April	Gear	2, 386	4.72	<0.01
	Area	3, 386	13.11	<0.01
	Interaction	6, 386	3.58	<0.01
May	Gear	2, 406	4.34	0.01
	Area	3, 406	5.68	co.01
	Interaction	6, 406	2.69	0.01
June	Gear	2, 421	7.25	<0.01
	Area	3, 421	12.30	<0.01
	Interaction	6, 421	3.28	<0.01
July	Gear	2, 537	1.09	0.34
	Area	3, 537	0.54	0.65
	Interaction	6, 537	1.04	0.40
August	Gear	2, 198	0.73	0.48
	Area	3, 198	0.48	0.70
	Interaction	6, 198	0.70	0.65

Appendix Table A- 10. **Analysis of variance statistics for comparisons of catch per unit effort of smallmouth bass between four areas of John Day Reservoir (forebay, Arlington, Irrigon and McNary tailrace),** 1986. **Analyses are based solely on electrofishing observations.**

Size class, month	df	F	*P*
250-400 mm:			
April	3, 145	10.60	<0.01
May	3, 165	5.15	a.01
June	3, 176	2.95	0.03
July	3, 293	2.33	0.07
August	3, 86	5.44	<O.Ol
>400 mm:			
April	3, 145	3.23	0.20
May	3, 165	7.23	<0.01
June	3, 176	4.99	<0.01
July	3, 293	2.73	0.04
August	3, 86	0.70	0.55

Appendix Table A-11. **Analysis of variance statistics for comparisons of catch per unit effort of northern squawfish between five areas[a] of John Day Reservoir (forebay, Arlington, Irrigon, McNary tailrace, and boat-restricted zone),** 1986. **Analyses are based solely on electrofishing observations.**

Size class, month	df	F	*P*
250-400 mm:			
April	4, 157	22.58	<0.01
May	4, 180	8.06	<0.01
June	4, 193	12.47	<0.01
July	4, 317	18.20	co.01
August	4, 95	9.91	<0.01
>400 mm:			
April	4, 157	23.05	co.01
May	4, 180	14.01	<0.01
June	4, 193	20.57	co.01
July	4, 317	40.63	<0.01
August	4, 95	22.06	co.01

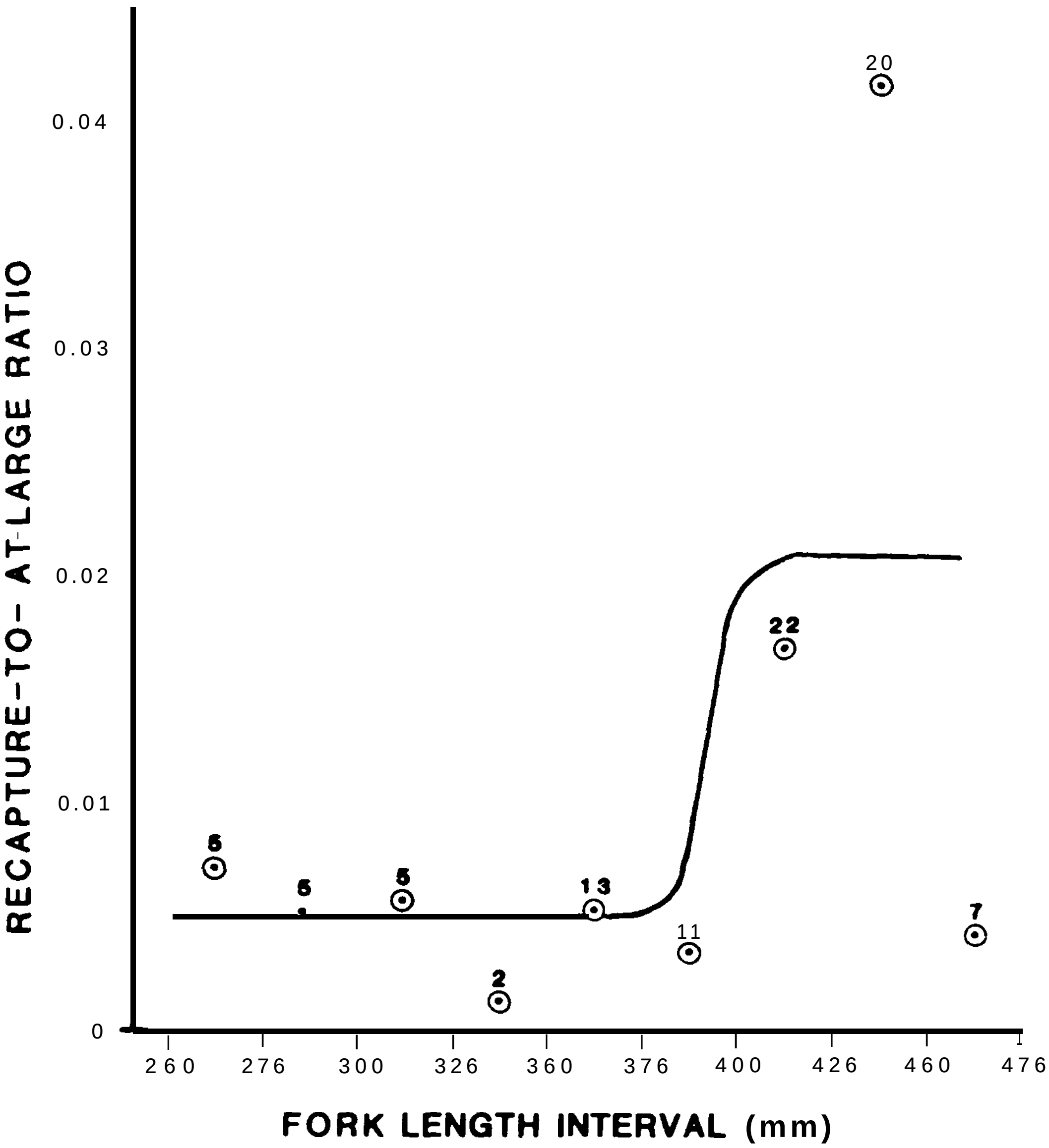

Figure A-1. Ratio of recaptures to marks at large (vulnerability) for northern squawfish by length interval, John Day Reservoir, March-June 1984-1986. Numbers of recaptures are included for each point. A line describing the relationship was smoothed by a moving average of 3 points and fit by inspection.

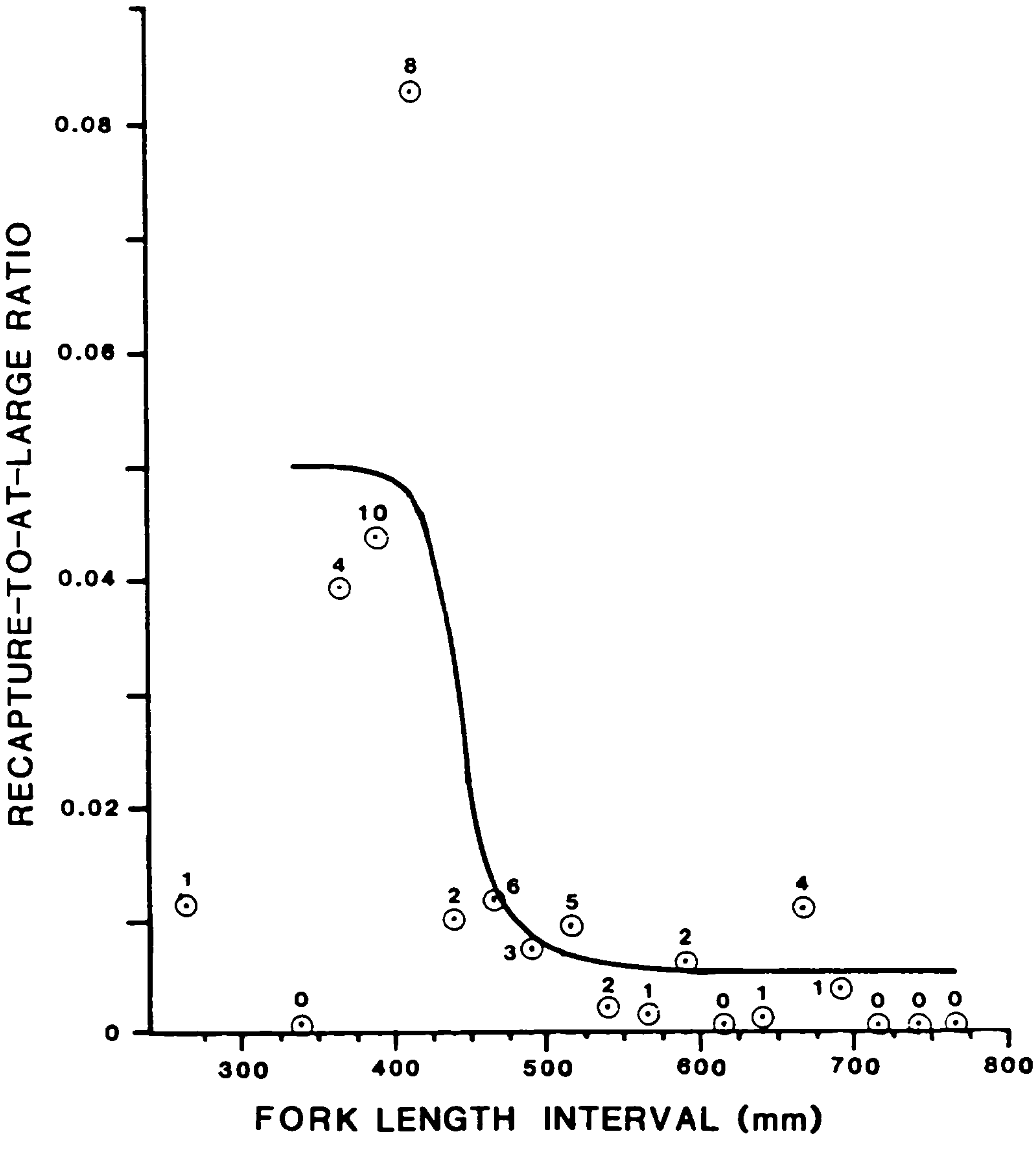

Figure A-2. Ratio of recaptures to marks at large (vulnerability) for walleye by length interval, John Day Reservoir, March-June 1983-1986. Numbers of recaptures are included for each point. A line describing the relationship was smoothed by a moving average of 3 points and fit by inspection.

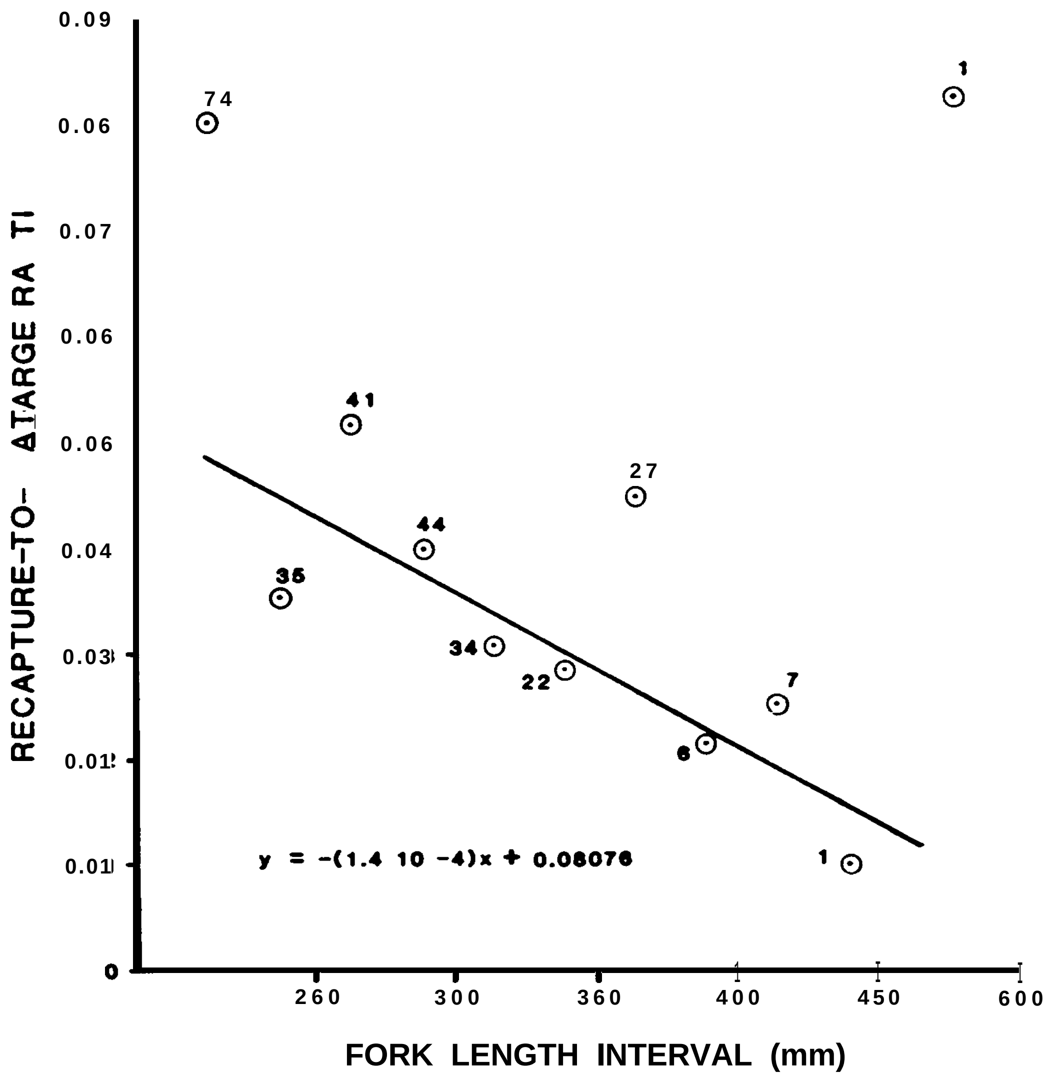

Figure A-3. Ratio of recaptures to marks at large (vulnerability) for smallmouth bass by length interval, John Day Reservoir, March-June 1984-1986. Numbers of recaptures are included for each point. A straight line describing the relationship was fit to the mean ratios with the least squares method.

APPENDIX B

Mark and Recapture Data Used to Estimate Abundance

Appendix Table B-l. Mark and recapture data for northern squawfish in John Day Reservoir, 25 March-l September 1986. Includes all reservoir areas, and fish larger than 249 mn fork length. No adjustments were made for estimated angler harvest.

Period	Catch	Recaptures	Number marked	Removals Unmarked	Removals Marked	Marked fish at large
7	197	0	167	29	0	0
8	297	4	185	106	0	167
9	295	0	148	146	2	352
10	288	4	147	135	3	498
11	563	5	287	271	1	642
12	726	5	276	442	5	928
13	601	3	262	322	1	1,199
14	932	10	211	710	8	1,460
15	352	9	183	157	7	1,663
16	610	8	19	259	7	1,839
17	2	0	0	2	0	1,851
Total	4,863	48	1,885	2,579	34	

Appendix Table B-2. Mark and recapture data for walleye in John Day Reservoir, 25 March-5 July 1986. Includes all reservoir areas, and fish larger than 249 mm fork length. No adjustments were made for estimated angler harvest.

Period	Catch	Recaptures	Number marked	Removals Unmarked	Removals Marked	Marked fish at large
7	48	0	40	8	0	0
8	78	0	77	1	0	40
9	56	0	54	2	0	117
10	57	1	50	5	0	171
11	71	1	47	23	0	221
12	49	1	39	9	0	268
13	71	2	28	35	0	307
Total	430	5	335	83	0	

Appendix Table B-3. Mark and recapture data for smallmouth bass in John Day Reservoir, 25 March-1 September 1986. Reservoir areas are seperated. The lower limit of fork lengths of fish included (249 mm) was adjusted 50 mm upward beginning in period 14 to minimize recruitment related to growth. Estimated harvest by anglers was included in removals in Forebay and Irrigon-Paterson areas.

Area, period	Catch	Recaptures	Number marked	Removals		Marked fish at large
				Unmarked	Marked	
Forebay:						
8	26	0	41	246	0	2
9	78	3	42	355	14	43
10	69	2	17	431	11	71
11	32	0	35	356	16	77
12	57	5	66	441	8	96
13	44	0	43	721	4	154
14	8	0	17	724	15	193
15	20	1	15	336	9	195
16	25	1	2	1,149	18	201
17	3	0	0	197	2	185
Total	362	12	280	4,964	97	
Arlington:						
7	3	0	3	0	0	0
8	24	0	24	0	0	3
9	47	0	47	0	1	27
10	79	3	73	0	1	73
11	93	5	81	0	3	145
12	83	3	67	3	0	223
13	24	1	18	0	1	290
14	26	0	21	1	0	307
15	58	1	29	0	0	328
16	26	0	2	1	0	357
17	0	0	0	0	0	359
Total	463	13	365	5	6	
Irrigon:						
7	13	0	8	5	0	0
8	46	3	41	1,215	4	8
9	63	2	50	42	6	45
10	88	6	61	465	21	89
11	120	4	102	146	16	129
12	134	3	117	10	7	215
13	179	10	45	149	4	325
14	12	3	5	64	4	366
15	55	5	37	63	2	367
16	18	2	1	50	6	402
17	0	0	0	9	0	397
Total	728	38	467	2,218	70	
McNary tailrace:						
7	1	0	1	0	0	0
8	6	0	6	0	0	1
9	4	0	3	1	0	7
10	6	0	6	0	1	10
11	42	0	38	4	0	15
	19	1	18	0	2	53
13	30	4	23	3	0	69
14	36	7	13	0	0	92
15	7	1	6	0	0	105
16	15	0	0	0	1	111
17	0	0	0	0	0	110
Total	166	13	114	8	4	

APPENDIX C

Angler Survey Data Used to Estimate Angler Harvest

Appendix Table C-l. Numbers of days available and of days surveyed during angler surveys in John Day Reservoir, 6 April-l September 1986.

Area, period	Weekdays		Weekends and holidays	
	Available	Surveyed	Available	Surveyed
Lower reservoir:				
8	10	4	4	2
9	10	4	4	2
10	10	4	4	2
11	9	3	5	3
12	10	4	4	2
13	14	4	7	2
14	10	4	4	4
15	10	3	4	2
16	10	4	4	1
17	10	4	6	3
Upper reservoir sloughs (Plymouth and Paterson):				
8	10	1	4	3
9	10	2	4	3
10	10	2	4	3
11	9	2	5	3
12	10	1	4	3
13	14	2	7	3
14	10	2	4	3
15	10	2	4	3
16	10	2	4	3
17	10	2	6	3
Upper reservoir main channel:				
8	10	2	4	3
9	10	2	4	3
10	10	2	4	2
11	9	0	5	4
12	10	2	4	3
13	14	2	7	3
14	10	2	4	5
15	10	1	4	3
16	10	1	4	3
17	10	2	6	4

Appendix Table C-2. Number angler counts made in John Day Reservoir, 6 April -1 September 1986. Counts began within one-half hour of the time indicated.

Location, time	Sampling Period									
	8	9	10	11	12	13	14	15	16	17	All
Lower reservoir:											
0600	2	2	3	2	1	2	3	0	2	2	19
0700	2	2	2	2	3	3	2	3	2	2 3	24
0800			2	1	2	3	2	3	1	2 2	0
0900	2	1	2	1	3	3	3	0	2	2	20
1000	2	2	1	1	2	1	2 21	333	31 2	2 3	22
1100							3	0	3	3	18
1200	42				4322			1			24
1300	1	22	1	2	0 2	2	3	2	1	3	20
1400	1	2	2	3	3 1 2	4	3	3	2	2	21
1500					3	3 0	33	01	2	3 3	18
1600	23		12	2		4	2	3		3	23
1700	33					4214					29
1800	1	1	2	3	2	1	3	2	2	3	20
1900	1	3	0	1	0	2	2	2	3	1	217
2000	1 0			0	0	0	0	0	0	0	0 1
Upper reservoir sloughs (Plymouth and Paterson):											
0600	0	1	1	1	1	0	2	1	1	0	8
0700	1	1	0	0	1	0	1	0	0	0	4
0800	2	3	2	1	0	1	1	1	1	1	13
0900	0	1	3	3	3	2	2	4	3	3	24
1000	2	1	0	1	1	2	2	0	1	1	11
1100	2	3	2	1	1	1	1	2	1	2	16
1200	1	1	2	3	2	2	2	3	3	2	21
1300	1	1	1	1	1	2	2	0	1	1	11
1400	2	3	2	1	0	1	2	2	1	1	15
1500	1	1	3	3	3	2	1	3	3	3	23
1600	0	2	1	1	1	2	2	1	2	1	13
1700	3	2	1	2	1	1	1	1	0	2	14
1800	1	0	2	1	1	3	1	2	2	2	15
1900	0	0	0	1	0	1	0	0	1	0	3
2000	0	0	0	0	0	0	0	0	0	0	0
Upper reservoir main channel:											
0600	1	1	1	1	0	2	1	0	0	0	7
0700	1	1	1	1	1	1	1	2	1	1	11
0800	0	0	1	1	3	2	1	0	2	2	12
0900	4	4	2	1	0	2	3	1	0	0	17
1000	1	1	1	2	3	1	3	3	2	4	21
1100	1	0	1	1	2	2	1	0	2	2	12
1200	3	4	2	1	0	2	3	1	0	0	16
1300	1	1	1	2	2	2	3	3	2	4	21
1400	1	0	1	1	3	1	1	0	2	2	12
1500	3	4	2	2	0	2	3	1	0	0	17
1600	0	1	1	1	3	2	3	3	2	5	21
1700	3	0	1	1	2	1	2	0	2	1	13
1800	1	3	1	1	0	0	1	1	1	0	9
1900	0	0	0	0	1	0	2	1	0	3	7
2000	0	0	0	0	0	0	0	0	0	0	0 0

Appendix Table C-3. Number of anglers interviewed in John Day Reservoir, 6 April-1 September 1986.

Area, angler type	Sampling Period 8	9	10	11	12	13	14	15	16	17	All
Lower reservoir:											
				0			2	0	4	0	
Boat, otheregeon	8D	90	82	123	110	89	105	63	56	46	8586
Bank, sturgeon	0	0	0	0	0	0	0	0	0	0	0
Bank, other	0	2	2	0	3	0	6	0	0	1	14
Upper reservoir:											
Boat, sturgeon	22	41	26	71	48	79	156	122	75	71	711
Boat, other	47	80	44	70	31	81	114	51	45	97	660
Bank, sturgeon	25	7	0	0	10	9	2	9	0	0	62
Bank, other	1	6	15	14	0	5	0	0	0	0	41

Appendix Table C-4. Estimated effort (hours) by anglers in John Day Reservoir, 6 April-1 September 1986.

Area, angler type	Sampling Period										
	8	9	10	11	12	13	14	15	16	17	All
Lower reservoir:											
Boat	1,935	2,558	2,440	5,815	4,865	7,488	3,161	2,572	5,638	2,495	39,007
Bank	351	339	218	315	266	353	387	368	353	379	3,329
Upper reservoir sloughs (Paterson and Plymouth):											
Boat	1,282	488	1,785	1,313	281	452	363	324	66	339	6,693
Bank	1,522	466	1,146	850	167	579	126	119	160	96	5,231
Upper reservoir main channel:											
Boat	2,109	1,836	2,611	2,621	2,196	7,944	7,951	6,092	5,307	6,523	44,190
Bank, sturgeon	1,993	1,448	1,438	1,492	2,027	4,291	4,023	2,322	3,028	2,467	23,529
Bank, shad	0	18	37	0	156	3,271	684	105	10	0	4,281
Bank, other	430	527	378	321	94	156	221	83	67	208	2,485

Appendix Table C-5. Catch per hour by anglers in John Day Reservoir, 6 April-1 September 1986.

Area, species angler type	Sampling Period 8	9	10	11	12	13	14	15	16	17	Combined
Lower Reservoir:											
Northern squawfish:											
Boat	0.096	0.194	0.231	0.156	0.057	0.102	0.042	0.041	0.054	0.044	0.106
Bank	0	0	0	0	0	0	0	0	0	0	0
Smallmouth bass:											
Boat	0.189	0.268	0.476	0.448	1.150	0.699	0.564	0.328	0.729	0.343	0.576
Bank	0	0.361	0	0	0	0	0.304	0	0	0	0.330
Channel catfish:											
Boat	0.010	0.002	0.002	0.060	0.050	0.034	0.021	0	0.003	0.009	0.024
Bank	0	0	0	0	0	0	0	0	0	0	0
Upper Reservoir:											
Northern squawfish:											
Boat	0.014	0.006	0.007	0.014	0.015	0.020	0.012	0.010	0.015	0.020	0.013
Bank, sturgeon	0	0	0	0	0	0	0	0	0	0	0
Bank, other	0	0	0	0	0	0.219	0	0	0	0	0.015
Walleye:											
Boat	0	0.004	0	0.002	0	0.005	0.008	0.017	0.006	0.006	0.007
Bank, sturgeon	0	0	0	0	0	0	0	0	0	0	0
Bank, other	0	0	0	0	0	0	0	0	0	0	0
Smallmouth bass:											
Boat	0.014	0.026	0.118	0.038	0.005	0.026	0.009	0.024	0.015	0.025	0.024
Bank, sturgeon	0	0	0	0	0	0	0	0	0	0	0
Bank, other	0.735	0	0.191	0.155	0	0.109	0	0	0	0	0.159
Channel catfish:											
Boat	0	0	0	0	0	0.003	0.001	0	0.002	0.001	0.001
Bank, sturgeon	0	0	0	0	0	0	0	0	0	0	0
Bank, other	0	0	0	0	0	0	0	0	0	0	0

Appendix Table C-6. Harvest per hour by anglers in John Day Reservoir, 6 April-1 September 1986.

Area, species angler type	Sampling Period 8	9	10	11	12	13	14	15	16	17	Combined
Lower Reservoir:											
Northern squawfish:											
Boat	0.014	0.058	0.170	0.061	0.018	0.064	0.014	0.021	0.010	0	0.044
Bank	0	0	0	0	0	0	0	0	0	0	0
Smallmouth bass:											
Boat	0.127	0.142	0.181	0.061	0.091	0.096	0.233	0.133	0.207	0.079	0.125
Bank	0	0	0	0	0	0	0	0	0	0	0.076
Channel catfish:											
Boat	0.010	0.002	0.002	0.060	0.050	0.030	0.016	0	0.003	0.004	0.024
Bank	0	0	0	0	0	0	0	0	0	0	0
Upper Reservoir:											
Northern squawfish:											
Boat	0.009	0.006	0.004	0.003	0	0.010	0.008	0.005	0.002	0.004	0.005
Bank, sturgeon	0	0	0	0	0	0	0	0	0	0	0
Bank, other	0	0	0	0	0	0.219	0	0	0	0	0.015
Walleye:											
Boat	0	0.004	0	0.002	0	0.005	0.008	0.012	0.006	0.005	0.006
Bank, sturgeon	0	0	0	0	0	0	0	0	0	0	0
Bank, other	0	0	0	0	0	0	0	0	0	0	0
Smallmouth bass:											
Boat	0.009	0.020	0.044	0.023	0.002	0.008	0.008	0.010	0.011	0.001	0.012
Bank, sturgeon	0	0	0	0	0	0	0	0	0	0	0
Bank, other	0.735	0	0.191	0.044	0	0.109	0	0	0	0	0.121
Channel catfish:											
Boat	0	0	0	0	0	0.001	0.001	0	0.002	0	
Bank, sturgeon	0	0	0	0	0	0	0	0	0	0	<0.001
Bank, other	0	0	0	0	0	0	0	0	0	0	0

Appendix Table C-7. Estimated and observed numbers[a] of unmarked and marked northern squawfish harvested by anglers, John Day Reservoir, 6 April-1 September 1986.

Area, status	Sampling period										
	8	9	10	11	12	13	14	15	16	17	All
Lower Reservoir:											
Unmarked:											
Estimated, interviews	28	150	409	355	86	479	44	53	54	0	1,658
Observed, interviews	6	33	74	42	17	30	6	6	3	0	217
Observed, voluntary[b,c]	0	0	1	1	0	0	0	1	1	0	4
Marked:											
Estimated, interviews	0	0	6	0	0	0	0				6
Estimated, voluntary[d]	0	2	1	0	0	0	0 0	20	0 0	0	5
Observed, interviews	0	0	1	0	0	0	0	0	0	0	1
Observed, voluntary[b]	0	1	0		0	0	0	1	0	0	2
Upper Reservoir:											
Unmarked:											
Estimated, interviews	29	14	16	12	0	241	58	34	7	26	437
Observed, interviews	3	3	1	0	0	9	00000	10	5 1	3	37
Observed, voluntary[b,c]	0	0	0								0
Marked:											
Estimated, interviews	0	0	0	0	0	0	6	0	0	0	6
Estimated, voluntary[d]	0	2	0	0	0	2	1	0	4	0	9
Observed, interviews	0	0	0	0	0	0	1	0	0	0	1
Observed, voluntary[b]	0	1	0	0	0	1	0	0	2	0	4

[a] *Includes fish* $\geq$ *250 mm in length.*
[b] *Includes areas outside those in which anglers were surveyed.*
[c] *Recaptures of fish tagged in* previous *years.*
[d] *Estimated from voluntary returns using an estimated return mte* of *50%* and *adding tags observed during angler interviews.*

Appendix Table C-8. Estimated and observed numbers[a] of unmarked and marked walleye harvested by anglers, John Day Reservoir, 6 April-1 September 1986.

Area, status	Sampling period 8	9	10	11	12	13	14	15	16	17	All
Lower Reservoir:											
Unmarked:											
Estimated, interviews	0	0	0	0	0	0	7	0	0	11	18
Observed, interviews	0	0	0	0	0	0	1	0	0	1	2
Observed, voluntary[b,c]	0	0	0	0	0	0	0	0	0	0	0
Marked:											
Observed, interviews	0	0	0	0	0	0	0	0	0	0	0
Observed, voluntary[b]	0	0	0	0	0	0	0	0	0	0	0
Upper Reservoir:											
Unmarked:											
Estimated, interviews	0	9	0	6	0	46	64	70	28	35	258
Observed, interviews	0	2	0	1	0	4	11	11	4	4	37
Observed, voluntary[b,c]	0	0	0	0	0	1	1	0	3	2	7
Marked:											
Estimated, interviews	0	0	0	0	0	0	0	6	0	0	6
Estimated, voluntary[d]	0	0	0	0	0	0	4	1	2	0	7
Observed, interviews	0	0	0	0	0	0	0	1	0	0	1
Observed, voluntary[b]	0	0	0	0	0	0	2	0	1	0	3

[a] *Includes fish ≥ 250 mm in length.*
[b] *Includes areas outside those in which anglers were surveyed.*
[c] *Recaptures of fish tagged in previous years.*
[d] *Estimated from voluntary returns using an estimated return rate of 50% and adding tags observed during angler interviews.*

Appendix Table C-9. Estimated and observed numbers[a] of unmarked and marked smallmouth bass harvested by anglers, John Day Reservoir, 6 April-1 September 1986.

Area, status	8	9	10	11	12	13	14	15	16	17	All
	Sampling period										
Lower Reservoir:											
Unmarked:											
Estimated, interviews	246	354	431	355	439	718	723	333	1,149	197	4,945
Observed, interviews	53	78	78	42	87	45	99	38	64	18	602
Observed, voluntary[b,c]	0	2	3	3	1	1	1	0	0	0	11
Marked:											
Estimated, interviews	0	14	11	0	5	0	15	9			72
Estimated, voluntary[d]	0	3	6	16	9	4	4	7	11	0	58
Observed, interviews	0	3	2	0	1	0	2	1	3	01	2410
Observed, voluntary[b]	0	0	2	8	4	2	1	3			
Upper Reservoir:											
Unmarked:											
Estimated, interviews	1,447	42	465	143	6	149	64	62	50	9	2,437
Observed, interviews	6	9	21	17	1	7	11	9	7	1	89
Observed, voluntary[b,c]	5	1	3	3	5	0	1	1	0	0	19
Marked:											
Estimated, interviews	0	5	21	0	0	0	0	0	0	0	26
Estimated, voluntary[d]	4	5	13	16	6	4	4	2	6	0	60
Observed, interviews	0	1	1	0	0	0	0	0	00		2
Observed, voluntary[b]	2	2	6	8	3	2	2	1	3	0	29

[a] *Includes fish > 200 mm in length.*
[b] *Includes areas outside those in which anglers were surveyed.*
[c] *Recaptures of fish tagged in previous years.*
[d] *Estimated from voluntary returns using an estimated return mte of 50% and adding tags observed during angler interviews.*

Appendix Table C-10. Estimated and observed numbers[a] of unmarked and marked channel catfish harvested by anglers, John Day Reservoir, 6 April-1 September 1986.

Area, status	Sampling period 8	9	10	11	12	13	14	15	16	17	All
Lower Reservoir:											
Unmarked:											
Estimated, interviews	19	5	5	349	243	225	51	0	17	10	924
Observed, interviews	4	1	1	41	48	14	7	0	1	1	118
Marked:											
Observed, interviews	0	0	0	0	0	0	0	0	0	0	0
Observed, voluntary[c]	0	0	0	0	0	0	0	0	0	0	0
Upper Reservoir:											
Unmarked:											
Estimated, interviews	0	0	0	0	0	8	8	0	9	0	25
Observed, interviews	0	0	0	0	0	1	1	0	1	0	3
Marked:											
Estimated, interviews	0	0	0	0	0	0	0	0	0	0	0
Estimated, voluntary[b]	0	0	0	0	2	6	0	0	2	0	10
Observed, interviews	0	0	0	0	0	0	0	0	0	0	0
Observed, voluntary[c]	0	0	0	0	1	3	0	0	1	0	5

*a Includes fish > **250** mm in length.*
b Estimated from voluntary returns using an estimated return mte of 50% and adding tags observed during angler interviews.
c Includes areas outside those in which anglers were surveyed.

Appendix Table C-11. **Length-frequency distributions of several fish species harvested by anglers in the John Day Reservoir, 6 April -1 Septemer** 1986.

			Smallmouth bass		Channel catfish	
Fork length interval (mm)	Northern squawfish	Walleye	Lower reservoir	Upper reservoir	Lower reservoir	Upper reservoir
150-175	2		1			
176-200	0		10	2	2	
201-225	3		41	10	3	
226-250	3		59	12	11	
251-275	1	1	82	14	10	
276-300	3	0	77	23	7	
301-325	0	0	53	13	5	
326-350	1	1	33	4	2	1
351-375	1	0	28	1	6	0
376-400	1	0	22	3	5	0
401-425	1	0	12	1	8	1
426-350	5	0	3	1	8	1
451-475	1	1	2		7	
476-500		2			3	
501-525		2			3	
526-550		1			3	
551-575		1			5	
576-600		4			4	
601-625		3				
626-650		3				
651-675		3				
676-700		9				
701-725		5				
726-750		2				
751-775		1				
776-800		2				
801-825		0				
826-850		2				

APPENDIX D

Tables at Backcalculated lengths

Appendix Table D-l. Mean backcalculated fork lengths (mm) the end of each year of life for northern squawfish from John Day Reservoir, 1982-86.

Year Class	AGE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1985	73																
1984	57	132															
1983	60	135	191														
1982	68	138	202	250													
1981	67	134	209	265	300												
1980	66	129	194	250	291	322											
1979	71	128	187	247	285	335											
1978	69	136	201	251	292	320	363	372									
1977	70	143	206	253	293	323	347	371	384								
1976	66	135	196	245	286	319	346	362	385	406							
1975	68	133	192	242	279	312	341	369	393	410	420						
1974	67	136	191	238	277	312	343	371	396	416	431	435					
1973	67	134	189	233	274	308	339	368	392	411	438	465	443				
1972	65	136	192	235	273	307	336	364	392	416	437	450	468	488			
1971	65	136	188	230	265	296	324	351	379	403	426	444	464	484	478		
1970	67	151	197	237	275	305	330	357	387	408	430	448	477	495	528		
1969	69	125	181	221	263	299	321	350	376	404	429	450	471	468			
1968	62	148	208	267	296	345	381	405	420	438	453	471	488	504	516	529	541
N	893	862	755	659	566	479	413	358	304	237	148	93	48	22	7	1	1
Mean	67	135	196	244	282	313	341	366	391	412	433	449	466	487	498	529	541
SD	19	22	26	28	27	28	30	31	33	36	31	32	26	22	28		
Increment	**67**	**68**	**61**	**48**	**38**	**31**	**28**	**25**	**25**	**21**	**21**	**16**	**17**	**21**	11	31	12

Appendix Table D-2. Mean backcalculated fork lengths (mm) at the end of each year of life for male northern squawfish from John Day Reservoir, 1982-86.

Year Class	AGE														
	1	2	3	4	5	6	/	8	9	10	11	12	13	14	15
1984	63	153													
1983	54	148	212												
1982	66	141	212	261											
1981	69	141	209	264	297										
1980	71	134	198	251	286	308									
1979	74	131	195	254	288	333									
1978	75	141	207	257	296	324	345	370							
1977	73	140	198	248	286	311	334	354	355						
1976	71	136	192	236	274	303	328	346	356	380					
1975	71	136	194	239	276	307	333	356	368	386	355				
1974	75	136	186	239	274	297	320	340	361	378	399				
1973	70	124	178	227	264	285	298	316	335	350	347	359			
1972	79	131	183	225	260	289	312	336	361	379	395	400	423		
1971	61	107	147	209	243	279	310	328	354	389	403	431	444	464	
1970	69	120	170	213	231	256	281	305	326	350	394	429	447	462	478
N	227	227	225	197	151	112	82	68	50	33	18	11	5	2	1
Mean	71	137	200	249	282	308	327	346	360	378	391	402	432	463	478
SD	16	20	25	26	27	26	25	26	25	28	26	24	26	2	
Increment	71	66	63	49	33	26	19	19	14	18	13	11	30	31	15

Appendix Table D-3. Mean backcalculated fork lengths (mm) at the end of each year of life for female northern squawfish from John Day Reservoir, 1982-86.

Year Class	AGE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1983	55	147	216												
1982	68	138	208	255											
1981	75	145	214	267	297										
1980	68	132	195	250	297	334									
1979	72	128	184	239	279	327									
1978	78	145	205	251	293	323	363	375							
1977	69	147	213	258	299	331	355	384	405						
1976	67	137	201	250	288	321	347	367	393	410					
1975	69	135	194	241	285	315	344	370	392	409	430				
1974	66	130	185	233	271	304	332	361	387	408	429	425			
1973	71	132	184	227	268	299	332	360	385	410	434	459	436		
1972	75	143	196	239	275	305	331	359	386	409	428	450	463	487	
1971	74	120	176	225	267	301	328	353	379	401	420	444	468	474	457
1970	68	133	191	228	268	313	343	370	399	423	451	467	477	499	515
N	323	323	322	289	241	204	177	156	134	105	72	40	19	6	2
Mean	70	137	199	246	283	315	341	365	389	409	430	446	460	483	486
SD	17	21	26	26	27	29	29	28	31	31	32	34	25	21	41
Increment	70	67	62	47	37	22	36	24	24	20	21	16	14	23	3

Appendix Table D-4. Mean backcalculated fork lengths (mm) at the end of each year of life for walleye from John Day Reservoir, 1982-86.

Year Class	AGE 1	2	3	4	5	6	7	8	9	10	11	12
1985	213											
1984	191	380										
1983	205	364	465									
1982	194	372	457	513								
1981	196	363	447	509	543							
1980	220	366	450	503	551	586						
1979	230	386	475	533	579	610	638					
1978	224	393	481	532	571	602	619	635				
1977	249	417	517	564	589	628	656	660	615			
1976	210	367	470	536	581	612	646	676	707	731		
1975	219	358	453	510	552	579	599	614	618	683	708	
1974	227	397	508	565	611	640	663	680	696	722	718	675
1973	232	404	513	572	617	645	671	686	699	714	752	772
1972	211	388	483	531	574	611	632	645	659	669	677	675
N	791	692	553	431	337	252	162	95	62	42	15	3
Mean	**217**	**380**	**475**	**535**	**579**	**615**	**644**	**662**	**677**	**712**	**724**	**707**
SD	37	50	60	66	67	70	71	78	82	67	54	56
Increment	**217**	**163**	**95**	**60**	**44**	**36**	**29**	**18**	**15**	**35**	**12**	

Appendix Table D-5. Mean backcalculated fork lengths (mm) at the end of each year of life for male walleye from John Day Reservoir, 1982-86.

Year Class	AGE 1	2	3	4	5	6	7	8	9	10	11	12
1985	238											
1984	**185**	**362**										
1983	211	377	482									
1982	192	367	454	505								
1981	196	369	456	504	558							
1980	228	369	452	495	543	580						
1979	221	374	455	505	538	566	594					
1978	212	381	467	515	551	578	607	633				
1977	247	415	510	551	571	595	619	633	609			
1976	221	368	464	529	576	607	632	653	675	708		
1975	214	354	442	500	540	568	584	599	602	680	712	
1974	217	378	494	530	575	603	624	639	652	673	679	675
1973	210	367	471	521	566	594	616	631	640	648	654	680
1972	222	373	458	516	570	615	639	652	666	674	680	675
N	295	281	259	214	170	137	89	54	28	19	10	4
Mean	**218**	**377**	**465**	**514**	**552**	581	612	633	638	670	675	676
SD	34	45	51	54	50	53	53	53	65	28	30	13
Increment	**218**	159	88	49	38	29	31	21	5	32	5	1

Appendix Table D-6. Mean backcalculated fork lengths (mm) at the end of each year of life for female walleye from John Day Reservoir, 1982-86.

Year Class	AGE 1	2	3	4	5	6	7	8	9	10	11	12
1985	242											
1984	228	418										
1983	212	406	489									
1982	202	373	410									
1981	205	377	503	606	660							
1980	231	405	494	542	593	582						
1979	238	396	498	561	619	664	668					
1978	236	410	509	567	600	633	636	627				
1977	263	441	546	601	634	662	693	718				
1976	212	368	483	541	579	601	621	633	655			
1975	196	344	489	565	624	659	681	699	710			
1974	231	396	524	585	649	683	708	723	735	810		
1973	243	418	541	610	661	690	721	738	752	774	772	772
N	129	123	112	101	83	61	35	20	15	11	5	1
Mean	232	400	507	572	621	657	685	709	737	784	772	772
SD	38	50	51	50	49	51	57	67	65	59	25	
Increment	232	168	107	65	49	36	28	24	28	47		

Appendix Table D-7. Mean backcalculated fork lengths (mm) at the end of each year of life for smallmouth bass from the lower John Day Reservoir, 1982-86.

Year Class	AGE 1	2	3	4	5	6	7	8	9	10	11
1985	83										
1984	80	179									
1983	82	154	255								
1982	79	155	235	334							
1981	74	145	227	309	386						
1980	78	140	213	265	329	399					
1979	80	136	193	245	298	342	386				
1978	90	157	222	271	320	346	383	423			
1977	83	143	215	271	313	351	378	402	452		
1976	75	137	197	267	312	335	383	397	415		
1975	89	171	247	316	369	399	421	443	460	474	492
N	645	564	407	265	190	98	52	24	8	2	1
Mean	80	149	214	269	309	350	382	407	449	474	492
SD	15	33	46	47	39	34	27	28	25	16	
Increment	80	69	65	55	40	41	32	25	42	25	18

Appendix Table D-8. Mean backcalculated fork lengths (mm) at the end of each year of life for smallmouth bass from the upper John Day Reservoir, 1982-86.

Year Class	AGE 1	2	3	4	5	6	7	8	9	10	11	12
1985	101	188										
1984	96	192										
1983	93	174	267									
1982	**103**	192	271	340								
1981	98	176	258	311	371							
1980	**95**	**177**	**255**	**323**	**361**	**405**						
1979	96	178	253	310	361	393	428					
1978	95	187	261	310	350	402	412	432				
1977	104	178	256	314	352	390	418	433	441			
1976	101	205	290	340	373	399	409	440	463			
1975	81	126	217	291	346	374	397	421	442			
1974	106	183	245	337	366	386	407	425				
1973	75	121	186	249	312	345	391	406	435	459	476	
1972	114	98	259	312	339	401	428	450	459	470		
1971	97	154	204	275	314	336	366	384	398	413	440	449
1970	132	250	310	333	356	382	398	413	422	435	450	463
N	564	501	376	231	148	88	54	32	15	4	3	2
Mean	**98**	**182**	**260**	**318**	**358**	**393**	**415**	**431**	441	444	455	456
SD	**17**	**29**	**36**	**36**	**31**	**24**	**26**	**24**	**23**	**26**	**18**	10
Increment	98	84	78	58	40	35	22	16	10	3	11	1

Appendix Table D-9. Mean backcalculated fork lengths (m) at the end of each year of life for male smallmouth bass from the lower John Day Reservoir, 1982-86.

Year	AGE 1	2	3	4	5	6	7
1984	99	244					
1983	87	172	269				
1982	79	158	253	335			
1981	73	202	275	337	378		
1980	84	165	256	319	375		
1979	77	128	177	232	273	328	380
N	41	41	33	16	5	2	1
Mean	85	178	253	314	315	328	380
SD	13	42	43	49	61	12	
Increment	85	93	75	61	1	13	52

Appendix Table D-10. **Mean backcalculated fork lengths** (mm) **at the end of each year of life for female smallmouth bass from the lower John Day Reservoir,** 1982-86.

Year Class	AGE 1	2	3	4	5	6	7	8	9
1984	104	252							
1983	85	171	284						
1982	81	159	247	333					
1981	81	127	203	271	420				
1980	81	167	238	203	357	401			
1979	79	140	199	254	307	332	376		
1977	88	158	234	291	335	366	394	418	473
N	63	59	54	44	25	17	11	4	2
Mean	85	163	237	295	329	360	389	418	473
SD	16	37	45	51	39	39	37	48	3
Increment	85	78	74	58	34	31	29	29	55

Appendix Table D-11. **Mean backcalculated fork lengths (mm) at the end of each year of life for male smallmouth bass from the upper John Day Reservoir,** 1982-86.

Year Class	AGE 1	2	3	4	5
1984	124	240			
1983	100	189	**290**		
1982	90	161	240	**313**	
1981	95	188	290		
1980	86	163	243	**298**	
1979	89	187	275	337	
1978	84	215	322	361	389
N	**31**	**31**	28	11	1
Mean	**95**	**179**	266	320	389
SD	**14**	**27**	32	22	
Increment	95	84	87	54	69

Appendix Table D-12. Mean backcalculated fork lengths (mm) at the end of each year of life for female smallmouth bass from the upper John Day Reservoir, 1982-86.

Year Class	AGE 1	2	3	4	5	6	7	8	9
1983	88	171	268						
1982	102	194	276	345					
1981	103	197	275	337					
1980	97	185	271	341	380				
1979	115	191	269	345	372	408	425		
1978	105	206	285	329	362				
1977	103	173	255	321	364	397	426	436	454
1976	100	234	318	363	385	406	425	440	
N	41	41	41	26	**17**	11	10	4	2
Mean	100	186	271	337	370	400	426	438	454
SD	16	25	29	28	21	11	10	8	9
Increment	100	86	85	66	33	30	26	12	16

APPENDIX E

Age Composition Data Used to Estimate Mortality

Appendix Table E-l. **Age-length-frequency distribution for northern squawfish in John Day Reservoir, 25 March-30 June** 1986.

Fork length interval (mm)	AGE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	**Sum**
51-75	3														3
76-100	3														3
101-125		10													10
126-150		9	1												10
151-175		5	5												10
176-200			8	2											10
201-225			8	2											10
226-250			1	7	1	1									10
251-275				7	3	0									10
276-300				5	3	2									10
301-325					6	4									10
326-350					54			1							10
351-375						3	2	2	2	1					10
376-400								2	5	1	2				10
401-425								2	0	1	5	1			9
426-450								1	4	2	1	2			10
451-475									0	1	4	2	2	1	10
476-500									111					33	9
501-525													1		1

Appendix Table E-2. Age-length-frequency distribution for walleye in John Day Reservoir, 25 March-30 June 1986.

Fork length interval (mm)	Age 1	2	3	4	5	6	7	8	9	10	11	12	Sum
151-175	5												5
176-200	10												10
201-225	10												10
226-250	10												10
251-275	10												10
276-300	7												7
301-325													0
326-350													0
351-375		8					1						9
376-400		7					1						8
401-425		5			1		0						6
426-450			7		0		0	1					8
451-475			10		0		0	0					10
476-500			6	4	0		0	0					10
501-525			2	4	3		0	0	1				10
526-550			1	2	5	2	0	0	0				10
551-575				1	3	4	2	0	0				10
576-600					1	3	5	1	0				10
601-625					0	1	7	1	1				10
626-650					0	1	3	4	2				10
651-675					1	1	5	1	1			1	10
676-700							10	0					10
701-725							31				22		8
726-750								0		0			0
751-775								0		0			0
776-800								1		1			2

Appendix Table E-3. Age-length-frequency distribution for small mouth bass in 1 ower John Day Reservoir, 25 March-30 J une 1986.

Fork length interval (mm)	**Age** 1	2	3	4	5	6	7	8	9	10	Sum
51-75	10										10
76-100	10										10
101-125	3	6	1								10
126-150		10	0								10
151-175		9	1								10
176-200		9	1								10
201-225		6	4								10
226-250		5	5								10
251-275		4	4	2							10
276-300		1	6	3							10
301-325			4	6							10
326-350			1	7	1		1				10
351-375				7	0	2	1				10
376-400				3	1	0	6				10
401-425					2	2	3	1	1		9
426-450						1		1	1		3
451-475									3		3
476-500										1	1

Appendix Table E-4. Age-length-frequency distribution for smallmouth bass in upper John Day Reservoir, 25 March-30 June 1986.

Fork length interval (mm)	Age 1	2	3	4	5	6	7	8	9	Sum	
51-75	10									10	
76-100	10									10	
101-125	10									10	
126-150	9	1								10	
151-175	1	9								10	
176-200	0	9	1							10	
201-225	1	7	2							10	
226-250		5	5							10	
251-275			10							10	
276-300			8	2						10	
301-325			3	6	1					10	
326-350			2	7	1					10	
351-375				9	0	1				10	
376-400				1	5	3	1			10	
401-425						3	4		12	10	
426-450						2	2		2	3	9
451-475							1		3	4	

Appendix Table E-5. Age composition of northern squawfish sampled in John Day Reservoir, 1983-86.

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Total
1983	18	133	59	11	33	221	349	244	313	391	86	36	16	23	1,933
1984	4	51	100	180	237	206	295	287	359	576	252	160	74	11	2,792
1985	4	51	357	987	238	152	200	403	463	470	440	138	164	22	4,089
1986	6	36	71	341	247	141	0	26	167	260	161	323	146	138	2,063

Appendix Table E-6. Age composition of northern squawfish estimated by adjusting the observed age composition for vulnerability to the sampling gear, John Day Reservoir, 1983-86.

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Sum
1983	18	133	59	39	364	823	1,177	906	728	796	86	36	16	21	5,202
1984	3	51	100	620	955	858	1,113	1,015	905	1,041	356	261	74	9	7,361
1985	4	54	357	3,729	934	630	623	973	1,065	862	439	137	163	22	9,992
1986	6	158	176	2,737	2,166	1,283	0	156	453	627	286	459	159	143	8,809

Appendix Table E-7. Age composition of walleye sampled in John Day Reservoir, 1983-86.

Year	Age 2	3	4	5	6	7	8	9	10+	Total
1983	75	110	364	64	44	6	6	13	25	707
1984	57	70	65	254	73	61	18	11	41	650
1985	80	35	21	42	307	68	33	0	18	604
1986	25	58	24	37	46	112	30	15	7	354

Appendix Table E-8. Age composition of walleye estimated by adjusting the observed age composition for vulnerability to the sampling gear, John Day Reservoir, 1983-86.

Year	Age 2	3	4	5	6	7	8	9	10+	Total
1983	77	373	2,349	536	435	82	59	129	251	4,291
1984	59	204	438	2,341	656	576	136	116	224	4,750
1985	82	107	97	374	2,943	683	322	0	209	4,817
1986	25	189	127	298	449	1,209	306	131	74	2,808

Appendix Table E-9. Age composition of smallmouth bass sampled in lower John Day Reservoir, 1983-86.

Year	Age 2	3	4	5	6	7	8	9	10+	Total
1983	120	94	18	15	5	1	1	1	1	256
1984	452	75	192	365	52	39	0	0	0	1,175
1985	414	795	72	92	356	33	95	4	3	1,864
1986	816	386	234	16	20	48	5	8	1	1,534

Appendix Table E-10. **Age composition of smallmouth bass estimated by adjusting the observed age composition for vulnerability to the sampling gear in lower John Day Reservoir,** 1983-86.

Year	Age 2	3	4	5	6	7	8	9	10+	Total
1983	120	98	22	18	9	4	2	2	2	277
1984	452	78	225	490	82	72	0	0	0	1,399
1985	416	845	91	121	566	60	193	8	12	2,312
1986	836	447	348	33	42	99	12	24	4	1,845

Appendix Table E-11. **Age composition of smallmouth bass sampled in upper John Day Reservoir,** 1983-86.

Year	Age 2	3	4	5	6	7	8	9	10+	**Total**
1983	74	137	108	31	23	11	6	2	0	392
1984	193	72	134	66	13	24	8	1	2	513
1985	88	304	22	58	41	2	28	6	0	549
1986	246	353	206	31	22	16	6	12	0	892

Appendix Table E-12. Age composition of smallmouth bass estimated by adjusting the observed age composition for vulnerability to the sampling gear in upper John Day Reservoir, 1983-86.

Year	Age 2	3	4	5	6	7	8	9	10+	**Total**
1983	75	166	157	55	49	26	15	7	0	550
1984	196	87	214	118	29	58	26	4	2	734
1985	88	376	28	105	99	5	65	12	0	778
1986	252	434	318	53	47	41	14	36	0	1,196

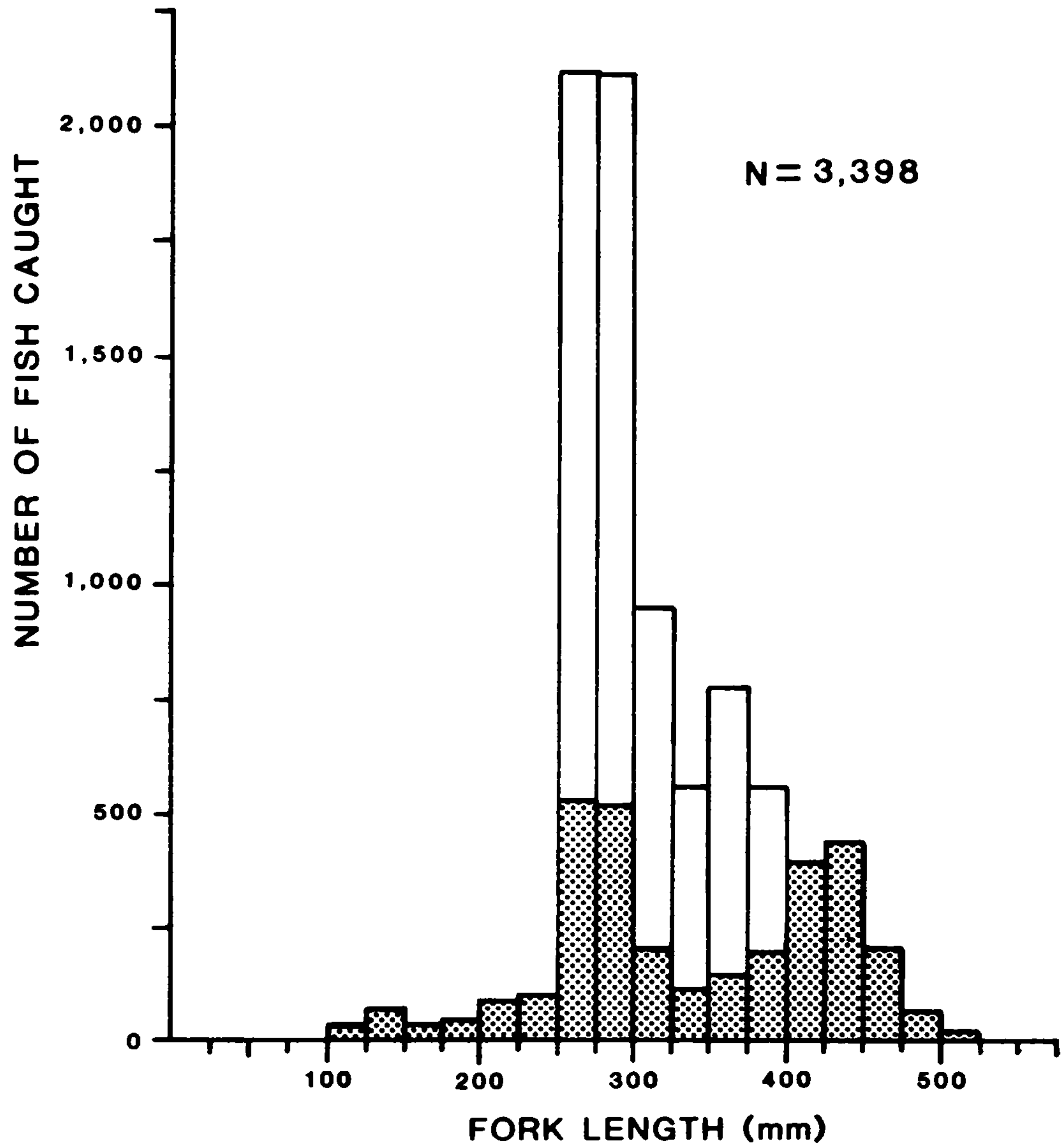

Figure E-1. Length-frequency distributions of northern squawfish collected in John Day Reservoir, March-June 1986. Length classes are adjusted from observed numbers (shaded) according to relative vulnerabilities to capture.

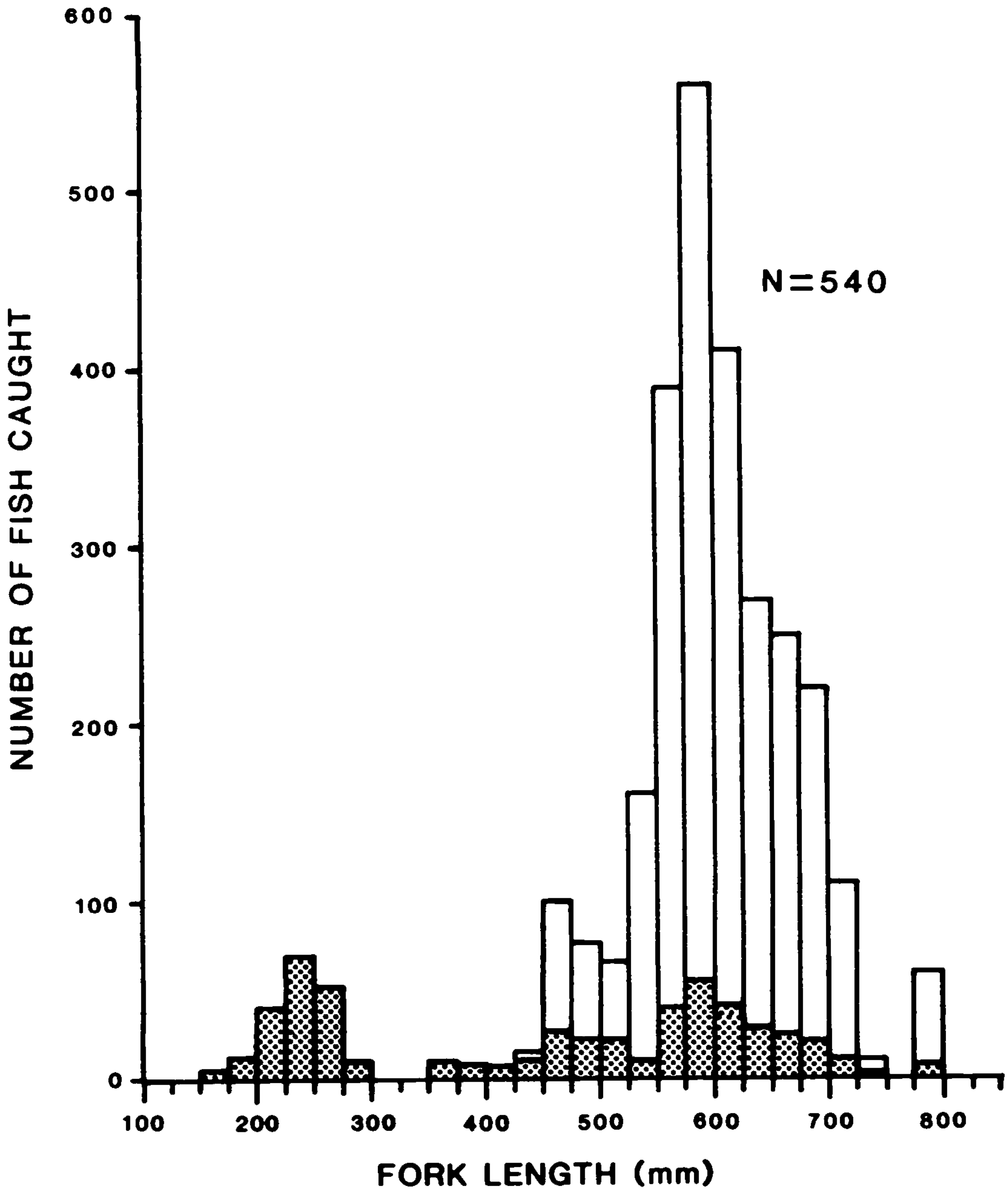

Figure E-2. Length-frequency distributions of walleye collected in John Day Reservoir, March-June 1986. Length classes are adjusted from observed numbers (shaded) according to relative vulnerabilities to capture.

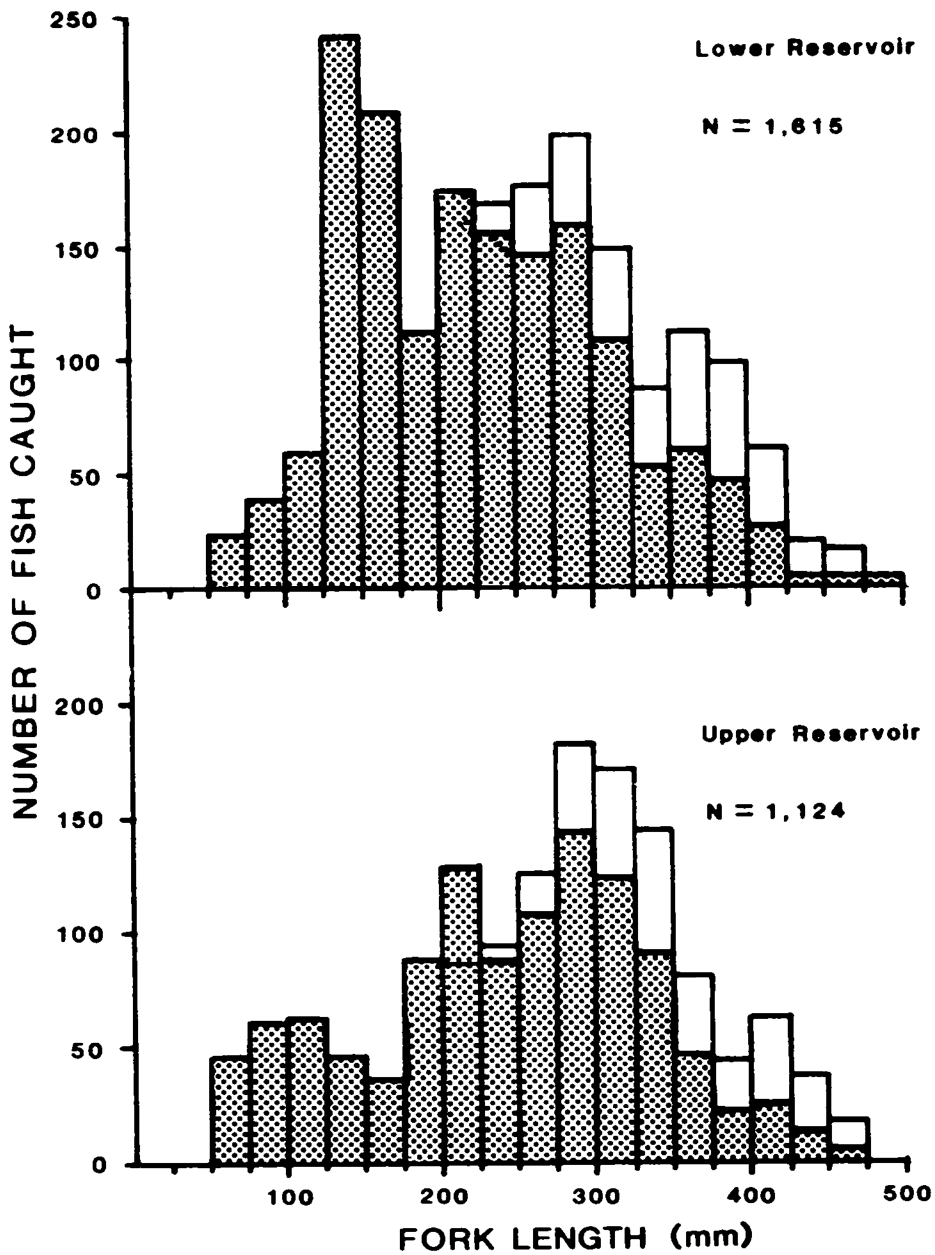

Figure E-3. Length-frequency distributions of smallmouth bass collected in John Day Reservoir, March-June 1986. Length classes are adjusted from observed numbers (shaded) according to relative vulnerabilities to capture.

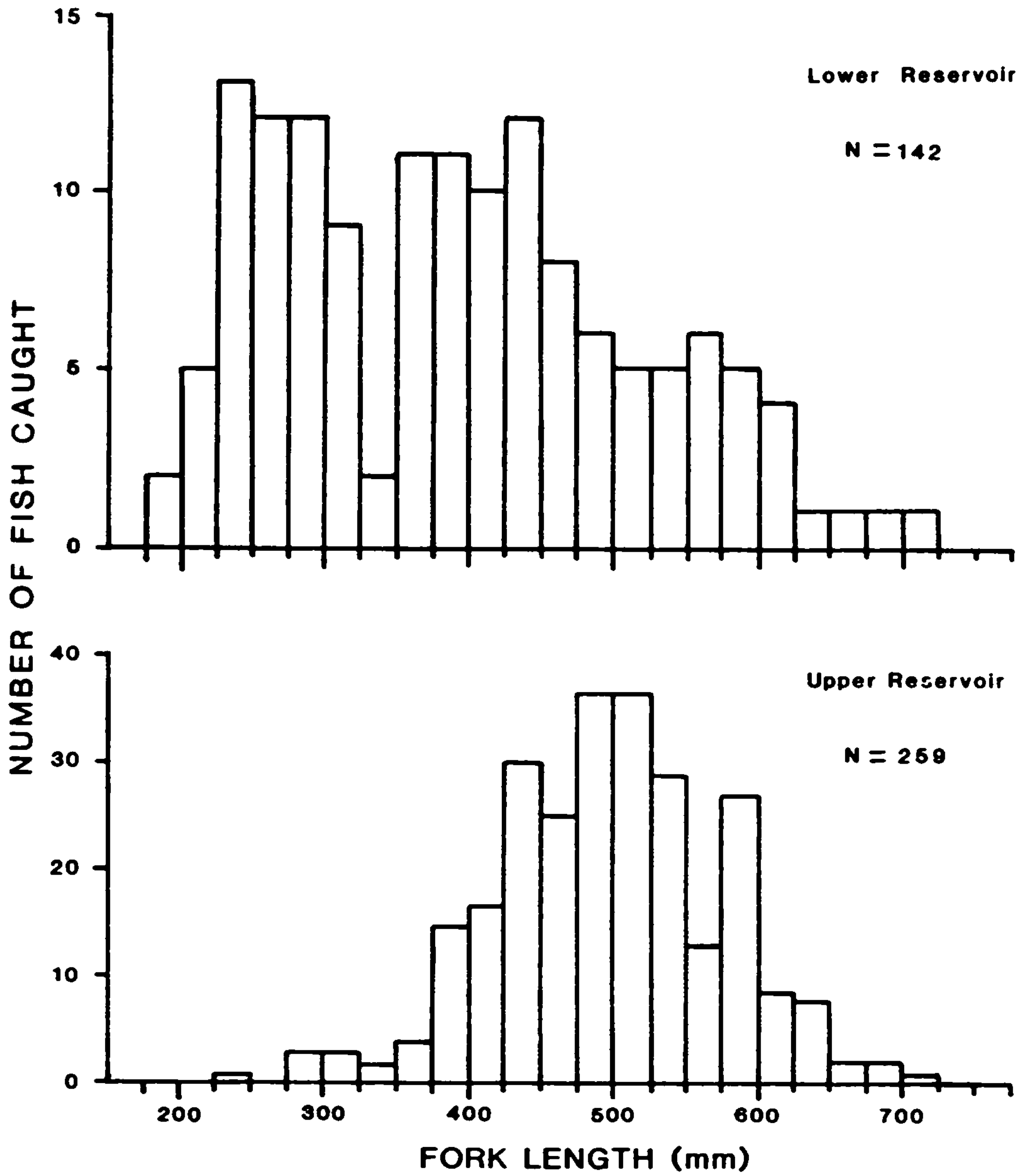

Figure E-4. Length-frequency distributions of channel catfish collected in John Day Reservoir, March-June 1986.

APPENDIX F

Estimates of Exploitation

Appendix Table F-l. Exploitation of northern squawfish approximated from tag recoveries in John Day Reservoir, 1984-86.

Year, statistic	Sampling period	Voluntary return	Corrected return	Tags at large	Exploitation
1984	8	0	0	35	0
	9	0	0	131	0
	10	1	2	311	0.006
	11	0	0	567	0
	12	1	2	832	0.002
	13	1	2	1,259	0.002
	14	6	13	1,554	0.008
	15	5	11	1,774	0.006
	16	2	4	2,217	0.002
	17	0	0	2,502	0
	18	0	0	2,502	0
	19	0	0	2,502	0
	20	1	2	2,552	0.001
Sum					0.027
Variance					0.00035
1985	8	0	0	41	0
	9	0	0	410	0
	10	1	2	642	0.003
	11	0	0	857	0
	12	1	2	1,274	0.002
	13	2	4	1,536	0.003
	14	3	6	1,854	0.003
	15	0	0	2,148	0
	16	2	4	2,414	0.002
	17	0	0	2,521	0
Sum					0.013
Variance					0.00001
1986	8	0	0	167	0
	9	2	4	352	0.011
	10	0	0	498	0
	11	0	0	643	0
	12	0	0	929	0
	13	1	2	1,203	0.002
	14	0	0	1,450	0
	15	1	2	1,572	0.001
	16	2	4	1,743	0
	17	0	0	1,845	0
Sum					0.014
Variance					0.00004

Appendix Table F-2. Exploitation of walleye approximated from tag recoveries in John Day Reservoir, 1984-86.

Year, statistic	Sampling period	Voluntary return	Corrected return	Tags at large	Exploitation
1984	8	0	0	0	0
	9	0	0	111	0
	10	0	0	138	0
	11	1	2	268	0.007
	12	1	2	338	0.006
	13	1	2	475	0.004
	14	2	4	556	0.007
	15	2	4	592	0.007
	16	5	11	601	0.018
	17	3	6	614	0.010
	18	1	2	608	0.003
	19	0	0	606	0
	20	1	2	606	0.003
Sum					0.065
Variance					0.00013
1985	8	0	0	0	0
	9	0	0	83	0
	10	0	0	138	0
	11	0	0	366	0
	12	1	2	440	0.005
	13	0	0	504	0
	14	3	6	498	0.012
	15	4	8	490	0.016
	16	1	2	488	0.004
	17	2	4	484	0.008
Sum					0.045
Variance					0.00009
1986	8	0	0	40	0
	9	0	0	117	0
	10	0	0	171	0
	11	0	0	221	0
	12	0	0	268	0
	13	0	0	307	0
	14	2	4	328	0.012
	15	0	0	349	0
	16	1	2	354	0.006
	17	0	0	362	0
	18	0	0	362	0
	19	1	2	362	0.006
Sum					0.024
Variance					0.00007

Appendix Table F-3. Exploitation of smallmouth bass approximated from tag recoveries in lower John Day Reservoir, 1984-86.

Year, statistic	Sampling period	Voluntary return	Corrected return	Tags at large	Exploitation
1984	8	0	0	3	0
	9	0	0	16	0
	10	5	11	90	0.120
	11	2	4	212	0.019
	12	7	15	346	0.043
	13	12	26	448	0.058
	14	15	33	630	0.052
	15	9	20	649	0.031
	16	4	8	694	0.011
	17	4	8	713	0.011
	18	1	2	707	0.003
	19	1	2	705	0.003
Sum					0.351
Variance					0.00166
1985	8	0	0	0	0
	9	4	9	31	0.290
	10	1	2	149	0.013
	11	1	2	196	0.010
	12	3	6	315	0.019
	13	1	2	342	0.006
	14	1	2	389	0.005
	15	0	0	393	0
	16	2	4	421	0.010
	17	1	2	422	0.005
	18	0	0		0
Sum					0.358
Variance					0.00690
1986	8	2	4	23	0.174
	9	0	0	65	0
	10	4	8	123	0.065
	11	9	19	169	0.112
	12	4	8	226	0.035
	13	2	4	285	0.014
	14	2	4	312	0.013
	15	3	6	355	0.017
	16	3	6	370	0.016
	17	2	4	407	0.010
	18	1	2	403	0.016
Sum					0.472
Variance					0.08800

Appendix G

Instantaneous and annual natural mortality approximated by the method of Pauly (1980) for John Day Reservoir.

Species	Natural Mortality Instantaneous	Natural Mortality Annual[a]
Northern squawfish:		
All	0.27	0.24
Males	0.28	0.25
Females	0.27	0.24
Walleye:		
All	0.47	0.37
Males	0.49	0.38
Females	0.42	0.33
Smallmouth bass:		
All--lower reservoir	0.42	0.35
All--upper reservoir	0.31	0.26

[a] Assumes total annual mortality of squawfish is 0.30, of walleye is 0.55, and of smallmouth is 0.40.

APPENDIX H

Correlation Matrixes Including Year-Class Strength and Potential Correlates

Appendix Table H-l. Correlation matrix of variables possibly influencing year-class strength of northern squawfish in John Day Reservoir.

Variable	(A)	(B)	(C)	(D)	(E)	(F)	(G)
(A) Year-class strength	1	-0.51	-0.87	-0.31	-0.63	0.63	0.03
(B) First year growth	-0.51	1	0.72	0.36	0.66	-0.61	-0.77
(C) Walleye year class[a]	-0.87	0.72	1	0.24	0.71	-0.59	-0.32
(D) Smallmouth year class[b]	-0.31	0.36	0.24	1	0.46	-0.52	0.13
(E) Water temperature[c]	-0.63	C.66	0.71	0.46	1	-0.95	-0.44
(F) Flowd	0.63	-0.61	-0.59	-0.52	-0.95	1	0.38
(G) Reservoir fluctuation[e]	0.03	-0.77	-0.32	0.13	-0.44	0.38	1
(H) Winter severity[f]	-0.33	0.51	0.35	-0.35	0.33	-0.38	-0.7

a Relative strength of concurrent walleye year class.
b Relative strength of concurrent smallmouth bass year class in upper reservoir.
c Mean daily water temperature (C)at McNary Dam during estimated spawning and incubation season.
d Mean daily reservoir flow (cfs) during estimated spawning and incubation season.
e Standard deviation of daily reservoir level (feet MSL) during estimated spawning and incubation season.
f Number of days during previous winter in which water tempemture at McNary Dam was less than 4.5 ‘C.

Appendix Table H-2. Correlation matrix of variables possibly influencing year-class strength of walleye in John Day Reservoir.

Variable	(A)	(B)	(C)	(D)	(E)	(F)
(A) Year-class strength	1	0.07	0.40	0.40	0.11	-0.49
(B) Rate of Temp. increase[a]	0.07	1	0.17	0.52	0.14	0.06
(C) First Year growth	0.44	0.17	1	-0.14	0.24	-0.53
(D) Strength of previous[b]	0.40	0.52	-0.14	1	0.12	-0.28
(E) Reservoir fluctuation[c]	0.11	0.14	0.24	0.12	1	0.39
(F) Flow[d]	**-0.49**	0.06	-0.53	-0.28	0.39	1

a *Rate* of *daily increase in wter temperature (C) at McNary Dam during estimated spawning and incubation season.*
b *Relative strength* of previous year's *walleye year class.*
c *Standard deviation of daily reservoir level (feet MSL) during estimated spawning and incubation season.*
d *Mean daily* reservoir *flow (cfs) during estimated spawning and incubation season.*

Appendix H-3. Correlation matrix of variables possibly influencing year-class strength of lower and upper reservoir smallmouth bass.

Area, variable	(A)	(B)	(C)	(D)	(E)
Lower reservoir:					
(A) Year-class strength	1	**0.29**	**0.95**	-0.77	0.18
(B) First Year growth	**0.29**	**1**	0.37	-0.24	0.16
(C) Water temperature[a]	**0.95**	0.37	1	-0.82	-0.04
(D) Flow[b]	-0.77	-0.24	**-0.82**	1	0.13
(E) Reservoir level[c]	0.18	0.16	-0.04	**0.13**	1
Upper reservoir:					
(A) Year-class strength	1	0.43	0.53	-0.54	0.01
(B) First Year growth	0.43	1	0.37	-0.24	0.16
(C) Water temperature[a]	0.53	0.37	1	-0.82	-0.04
(D) Flow[b]	-0.54	-0.24	-0.82	1	0.13
(E) Reservoir level[c]	**0.01**	**0.16**	-0.04	**0.13**	1

a Mean daily water temperature (C) at McNary Dam during spring and summer.
b Mean daily reservoir flow (cfs) during spring and swnner.
c Mean daily reservoir level (feet MSL) during spring and summer.